SCIENCE 10

Module 4

Energy Flow in Global Systems

Learning Technologies Branch

Alberta EDUCATION

Science 10

Module 4

Energy Flow in Global Systems

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Science 10
Module 4: Energy Flow in Global Systems
Student Module Booklet
Learning Technologies Branch
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Other	

You may find the following Internet sites useful:

- Alberta Education, **http://www.education.gov.ab.ca**
- Learning Technologies Branch, **http://www.education.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.education.gov.ab.ca**

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Welcome to SCIENCE 10

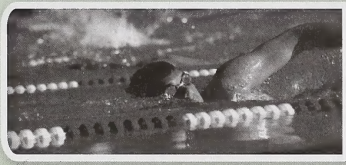
Module 4

Module 1 contains general information about the course components, additional resources, icons, assessment, and strategies for completing your work.

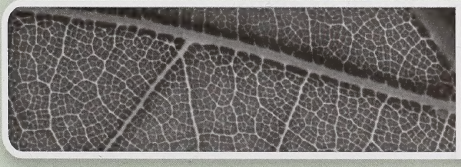
If you do not have access to Module 1, contact your teacher to obtain this important information.

It is recommended that you work through the modules in order (from 1 to 4) because concepts and skills introduced in one module will be reinforced, extended, and applied in later modules.

Module 1
Energy and Matter in Chemical Change



Module 2
Energy Flow in Technological Systems



Module 3
Cycling Matter in Living Systems

Module 4
Energy Flow in Global Systems

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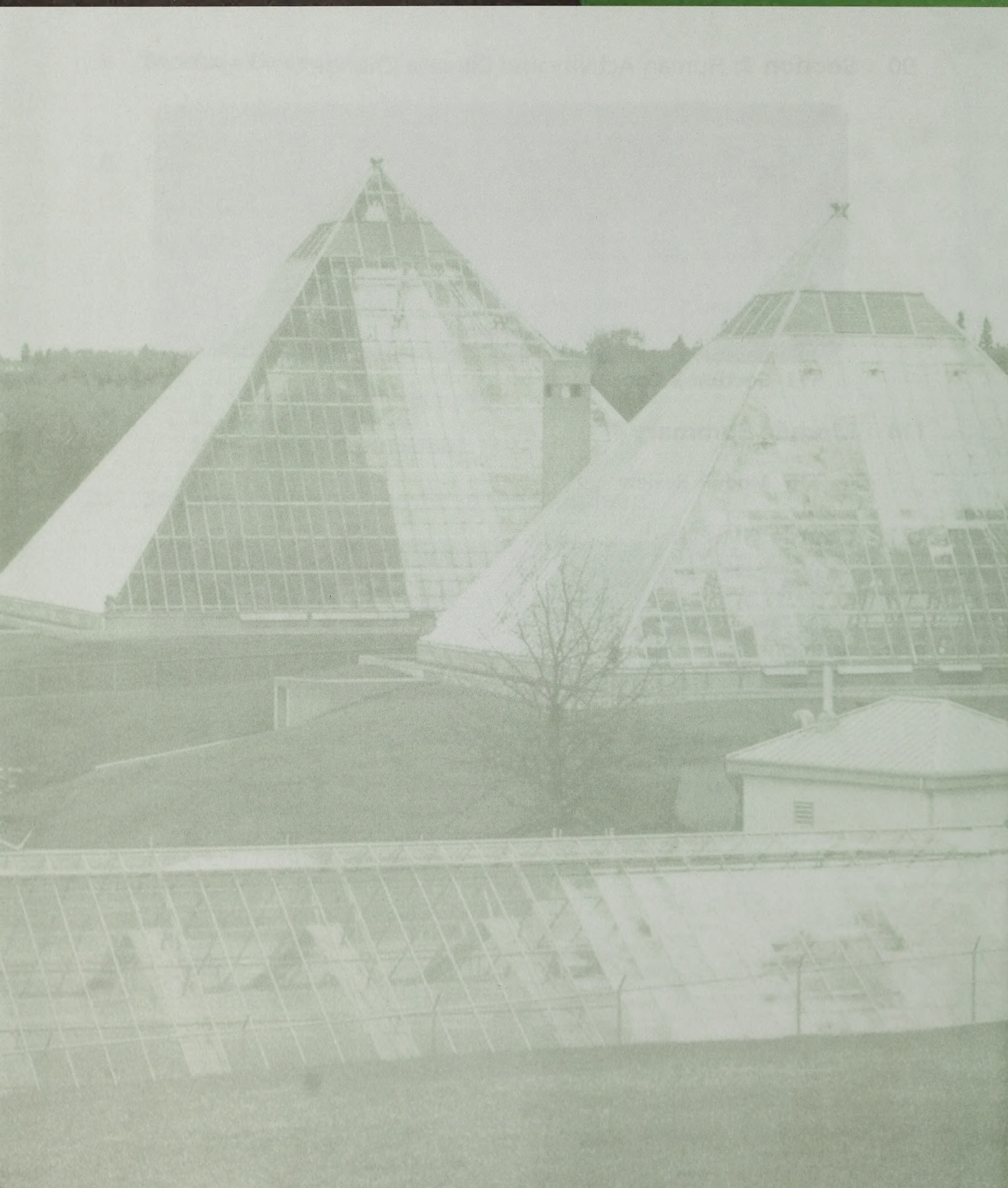
Module Overview



Have you ever visited the Muttart Conservatory in Edmonton or even a local greenhouse? These structures control the interior environment so plant life can be sustained even when the outside weather is too harsh for the plants. The Muttart Conservatory displays an array of exotic plants that would never survive in Edmonton's climate on their own.

Structures that provide a protected environment for plants are usually made of glass. The glass allows solar energy (in the form of sunlight) to reach the plants inside. You already know that such solar energy is essential for plant photosynthesis. But did you know that solar energy is also important in maintaining the global climate systems of the world beyond the protected environments of conservatories and greenhouses?

In this module you will investigate the importance of solar energy in supporting life on Earth and maintaining global climate systems. You will see how the flow of thermal energy converted from solar energy results in a variety of climate zones with characteristic weather patterns and biomes. You will then examine evidence that indicates climate change has happened in the past. Later, you will evaluate evidence relating to the question, "Does human activity accelerate global climate change and what could be the impact on biomes?"

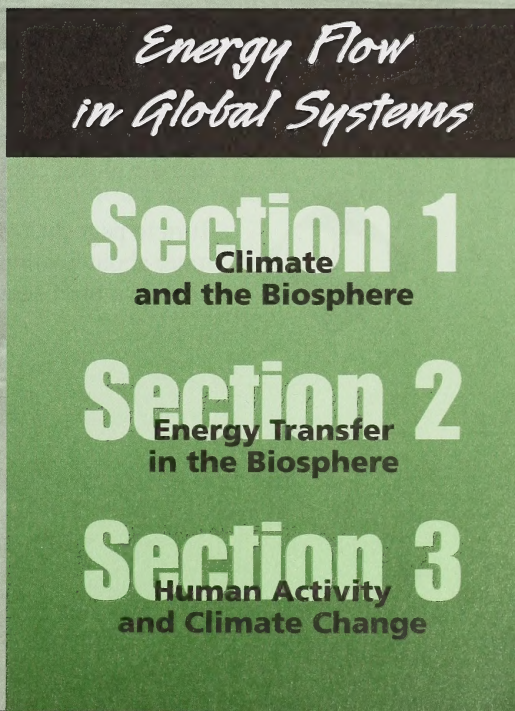
Check out "Focus on Social and Environmental Context" on page 339 of the textbook to see what's ahead in this module. Then read "Exploring" on page 340 and 341 for an introduction to issues relating to global climate change.

Assessment

This module, Energy Flow in Global Systems, has three section assignments. The mark distribution is as follows:

Assignment Booklet 4A	
Section 1 Assignment	24 marks
Assignment Booklet 4B	
Section 2 Assignment	64 marks
Assignment Booklet 4C	
Section 3 Assignment	47 marks
TOTAL	**135 marks**

Be sure to check with your teacher if this mark allocation is valid for you. Some teachers may include other reviews and assignments for additional assessment.



Climate and the Biosphere

Do you enjoy cross-country skiing? How about snowshoeing? If so, you can look forward to conditions in Alberta to be right for both cross-country skiing and snowshoeing in the winter. This expectation comes from knowing the climate of this province.

The climate of a region is based on the average weather conditions of that region over a period of many years. The climate in Alberta, for instance, involves snow and temperatures well below 0°C for several months. Climate conditions are not just important to your recreational activities, they have an impact on the entire biosphere—the thin layer around Earth where living things exist.

In this section you will describe the composition of the biosphere and explain how climate keeps the biosphere suitable for life. You will also examine some evidence that the global climate may be changing.

Turn to page 342 of the textbook and read the introduction to Unit D 1.0 for more about Section 1. Note the key concepts and learning outcomes listed. They provide a brief summary of what you will cover in this section.

Lesson 1

Earth's Biosphere

biosphere: a relatively thin layer of Earth that has conditions suitable for life

The **biosphere** extends from the depth of the oceans to well beyond the highest peaks inhabited by mountain goats and bighorn sheep. Yet, compared to the Earth itself, the biosphere is only a thin layer.

Turn to page 343 of the textbook and read the introductory paragraphs of "Earth—Our Biosphere."

1. Match each description with a term from the following list.

   i. atmosphere ii. climate iii. lithosphere
   iv. biosphere v. hydrosphere

   a. the envelope of Earth that includes bodies of water and water vapour in the air

   b. the layer of gases surrounding Earth

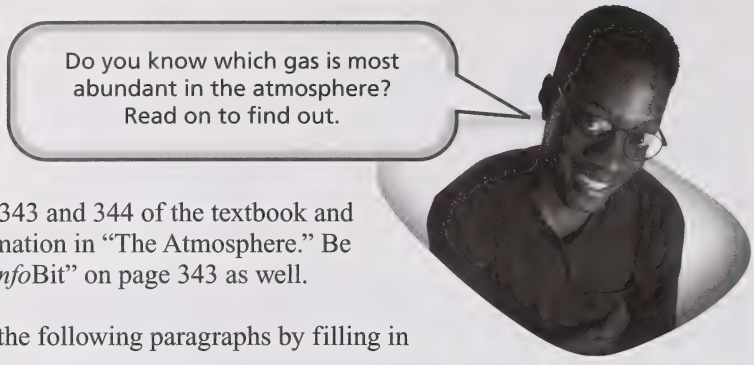
   c. the layer of Earth that can support life

   d. the solid, outer portion of Earth

Check your answers with those on page 14.

atmosphere: the layer of gases that surround Earth

Every breath you take reflects your need and the need of other living things for oxygen. Oxygen is a significant portion of the **atmosphere**. But the most abundant gas of the atmosphere is not oxygen.



Turn to pages 343 and 344 of the textbook and read the information in "The Atmosphere." Be sure to read "*info*Bit" on page 343 as well.

2. Complete the following paragraphs by filling in the blanks.

   _____ and _____ gases make up 99% of the atmosphere. _____ gas is essential for plant growth. _____ gas is released into the atmosphere during photosynthesis by plants and is consumed by living things during respiration. _____ gas is used up during the combustion of fuels, and _____ gas controls the amount of combustion

3. Why do you think atmospheric dust stays suspended?

Check your answers with those on pages 14 and 15.

Earth's atmosphere is unique in comparison to the atmospheres of neighbouring planets. In the next activity you will make a clear, visual presentation to compare atmospheres of Earth with some of its neighbouring planets.

Quicklab

Modelling Atmospheres

Read the entire activity on page 344 of the textbook.

Carefully follow the steps outlined in the procedure.

4. Print out or draw the final version of your graph.

5. Answer questions 1 and 2 of "Questions."

Check your answers with those on pages 15 and 16.

Have you visited the Rocky Mountains in the summer? Even during the warm summer months you can see snow-capped mountains. This is because the snow is at a high **altitude**, where the temperature remains cold.

altitude: the distance above Earth's surface measured from sea level

troposphere: the atmospheric layer from 0 km to 10 km above Earth's surface

mesosphere: the atmospheric layer above the stratosphere, from 50 km to 80 km above Earth's surface

From this observation, you might predict that temperature decreases with altitude. This relation is true for the **troposphere** and the **mesosphere** but not for the other layers of the atmosphere. The next reading describes the temperature and composition of the layers of Earth's atmosphere.

Turn to page 345 of the textbook and read "Troposphere" and "Stratosphere, Mesosphere, and Thermosphere." Examine Figures D1.4 and D1.5 closely.

In the next activity you will investigate samples of air temperature data from two western Canadian cities.

Inquiry Lab

Air Temperature and Altitude

Read the entire activity on page 347 of the textbook.

6. What is the responding variable?

7. Graph the data according to step 1 of the procedure.

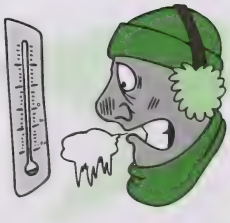
8. Answer the following on page 347 of the textbook.

   a. questions 1 and 2 of "Analyzing and Interpreting"
   b. questions 3 and 4 of "Forming Conclusions"
   c. question 5 of "Applying and Connecting"

Check Check your answers with those on pages 16 and 17.

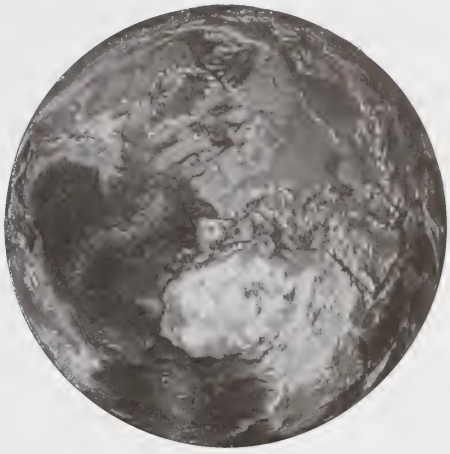
Did You Know?

Mount Everest, the highest mountain in the world, has an average summit temperature of –36°C in January, the coldest month of the year. It has even been known to reach –60°C. In July, the warmest month of the year, the average summit temperature reaches only –19°C. Temperatures never rise above freezing.



The relationship between altitude and temperature in the troposphere is a general one. However, exceptions do occur. Learn more by reading "Altitude and Temperature" on page 348 of the textbook.

Now, turn to page 346 of the textbook and read "The Lithosphere," "The Hydrosphere," and "The Components of the Biosphere Interact." You will gain a better understanding of the components of the lithosphere and hydrosphere, and you will examine how these components, along with those of the atmosphere, interact.



9. Answer questions 3, 7, and 8 of "Check and Reflect" on page 348 of the textbook.

Check Check your answers with those on page 18.

Looking Back

10. Answer question 11 of "Check and Reflect" on page 348 of the textbook.

Check Check your answer with the one on page 18.

Go to ... Go to pages 1 and 2 of Assignment Booklet 4A and answer questions 1 to 8.

Glossary

altitude: the distance above Earth's surface measured from sea level

atmosphere: the layer of gases that surround Earth

atmospheric dust: tiny, solid particles suspended in the atmosphere

biosphere: a relatively thin layer of Earth that has conditions suitable for life

climate: the average weather conditions that occur in a region over a long period of time

hydrosphere: the water on Earth, whether present as liquid, water vapour, or ice

inversion: a reversal of normal temperature patterns seen in the troposphere

In an inversion, there is an increase of temperature with height through a layer of air.

lithosphere: the solid outer portion of Earth, composed of rocks, minerals, and elements

mesosphere: the atmospheric layer above the stratosphere, from 50 km to 80 km above Earth's surface

ozone: a molecule composed of three atoms of oxygen

ozone layer: a layer in the stratosphere containing high levels of ozone gas

stratosphere: the atmospheric layer above the troposphere, from 10 km to 50 km above Earth's surface

thermosphere: the highest atmospheric layer, from 80 km to 300 km above Earth's surface

troposphere: the atmospheric layer from 0 km to 10 km above Earth's surface

weather: the state of the atmosphere at a particular place and time with regard to temperature, air pressure, cloud cover, precipitation, and humidity

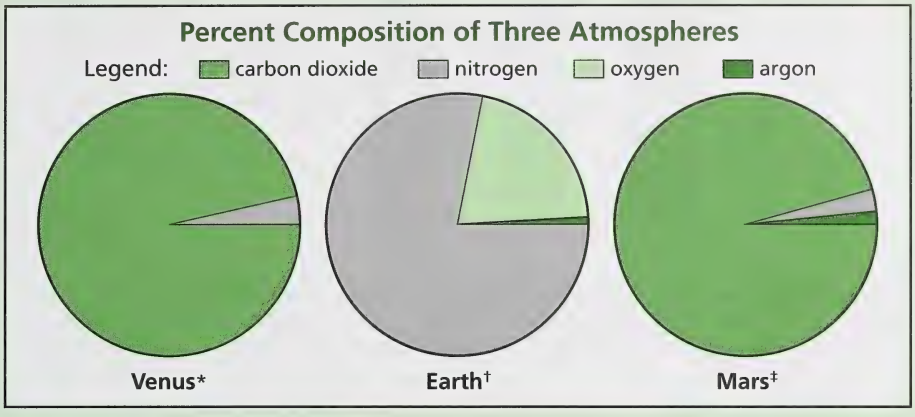
Suggested Answers

1. a. v b. i c. iv d. iii

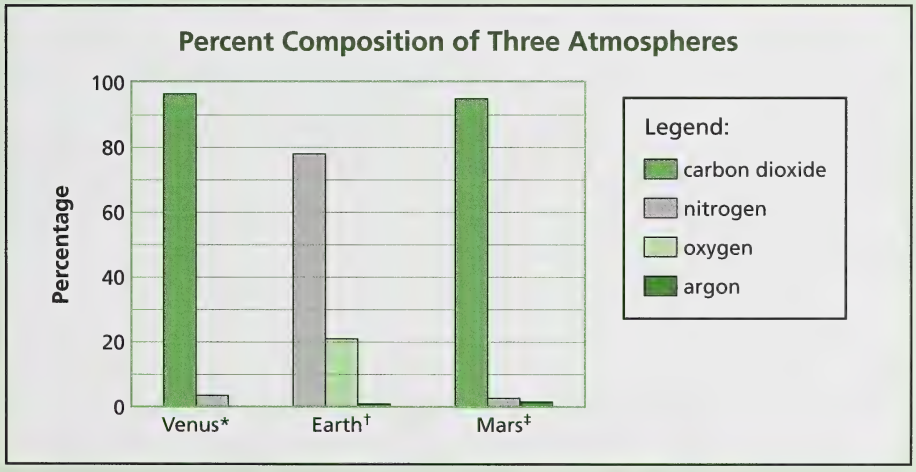
2. **Nitrogen** and **oxygen** gases make up 99% of the atmosphere. **Nitrogen** gas is essential for plant growth. **Oxygen** gas is released into the atmosphere during photosynthesis by plants and is consumed by living things during respiration. **Oxygen** gas is used up during the combustion of fuels, and **nitrogen** gas controls the amount of combustion.

3. Atmospheric dust stays suspended because it is composed of very tiny particles. These tiny particles fall very slowly in the air.

4. Graphs may vary. A series of pie graphs or a bar graph would show this information clearly. Sample graphs are given.



* Venus's atmosphere also contains trace amounts of oxygen and argon gases.
† Earth's atmosphere also contains trace amounts of carbon dioxide and methane gases.
‡ Mars's atmosphere also contains trace amounts of oxygen gas.



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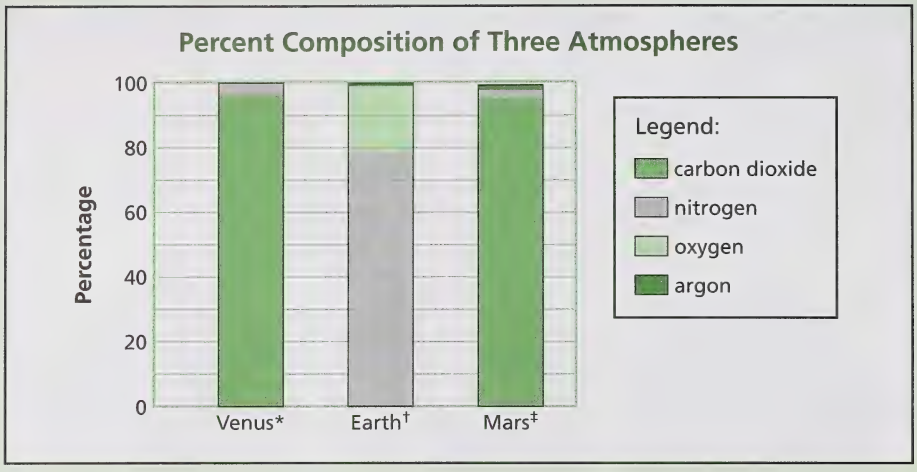


* Venus's atmosphere also contains trace amounts of oxygen and argon gases.
† Earth's atmosphere also contains trace amounts of carbon dioxide and methane gases.
‡ Mars's atmosphere also contains trace amounts of oxygen gas.

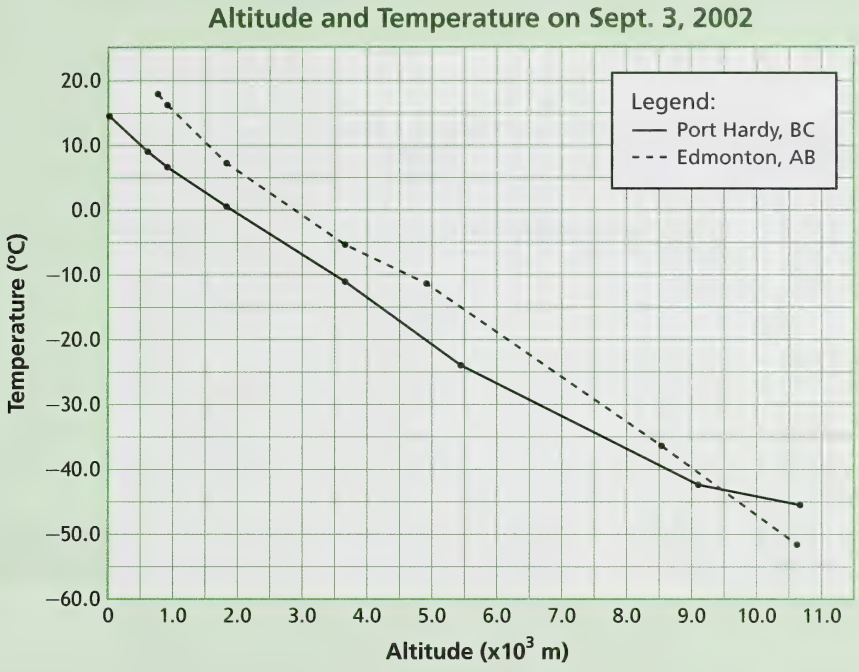
5. **Textbook questions 1 and 2 of "Questions," p. 344**

    1. Answers will vary. The bar graph and pie graph clearly show how Earth's atmosphere is different compared to those of Venus and Mars. These graphs show the presence of oxygen gas and the lack of carbon dioxide gas in Earth's atmosphere. The graphs also show the abundance of nitrogen gas in Earth's atmosphere compared to the atmospheres of the other planets.

    2. Earth has a high level of oxygen and almost no carbon dioxide compared to Venus and Mars. With such low levels of oxygen, Venus and Mars are unlikely able to support life as we know it. Both plants and animals need oxygen for respiration.

6. The responding variable is temperature.

7. Your graph should look similar to the following.



8. a. **Textbook questions 1 and 2 of "Analyzing and Interpreting," p. 347**

   1. Edmonton had the higher temperature at an altitude of 914 m. At an altitude of 10 668 m, Port Hardy had the higher temperature.

   2. At 4000 m, Edmonton's temperature is about −7°C and Port Hardy's is about −13°C.

   b. **Textbook questions 3 and 4 of "Forming Conclusions," p. 347**

   3. As the altitude increases, the temperature decreases.

   4. The trend shown by the graph of temperature versus altitude is typical for the troposphere, where temperature decreases with altitude.

   c. **Textbook question 5 of "Applying and Connecting," p. 347**

   5. The Rockies are much higher than the Laurentians. Both terrains are in the troposphere where temperature decreases with altitude. Therefore, the climate in the Rockies is generally colder than the climate in the Laurentians. Evergreens cover much of the Rockies because they are better adapted to colder climates than deciduous trees.

9. **Textbook questions 3, 7, and 8 of "Check and Reflect," p. 348**

   3. The biosphere has three components:

      - **the atmosphere**: the layer of gases that surround Earth
      - **the hydrosphere:** consists of all the forms of water on Earth, whether present as liquid, water vapour, or ice
      - **the lithosphere:** the solid, outer portion of Earth, composed of rocks, minerals, and elements

   7. Most of Earth's weather events occur in the troposphere.

   8. The lithosphere includes more than just the land making up the continents. It includes the land under the ocean and other bodies of water.

10. **Textbook question 11 of "Check and Reflect," p. 348**

11.

Similarities		
• part of the biosphere • interacts with other components of the biosphere • provides conditions that support life		
Differences		
Lithosphere	**Hydrosphere**	**Atmosphere**
• consists of Earth's surface and about 100 km below • composed of a mixture of solids	• mainly on Earth's surface (97% is in oceans) • composed of only water in solid, liquid, or gas phase	• lies above Earth's surface • composed of a mixture of gases, known as air, and some dust

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Lesson 2

Climate

An igloo is a traditional Inuit dwelling usually made of blocks of snow in the form of a dome. Clearly, the igloo was designed for cold climates. Climate affects people—what they live in, what they eat, what they wear, and what they do. In fact, climate affects all organisms.

Turn to pages 349 and 350 of the textbook and read "Climate Affects Daily Life."

Going Further

Climates in Canada vary a lot. In this activity you can examine data from many locations. For data on climate in your region, go to the following Environment Canada website:

http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

This site provides climate conditions in terms of averages and extremes for many locations. Start by comparing the climate data of a site in northern Alberta with a site in southern Alberta.

1. Describe how climate affects human population density in regions within Canada. Give an example.

2. Explain why houses in some regions of California have no need for a chimney.

3. Why is the Okanagan Valley in British Columbia a better region for farmers to grow fruit than the region around High Level, Alberta? **Hint:** You may need to refer to a map.

Check your answers with those on page 24.

You have seen how climate has affected people in many ways. The fact of the matter is that all living things in a region are affected by the climate.

Turn to pages 350 and 351 of the textbook and read "Climate Affects All Organisms."

4. Answer question 2 of "Check and Reflect" on page 354 of the textbook.

Check your answer with the one on page 24.

Next is an activity involving examining the role of climate for three particular species in Canada— the Arctic wolf, the trumpeter swan, and the purple lilac.

Turn to page 351 of the textbook and read "Minds On . . . The Importance of Climate."

5. Indicate how you think the Arctic wolf, trumpeter swan, and purple lilac would be affected by an increase in temperature.

If you do not have a group to work with, you may ask a friend or family member to help you. Do your brainstorming according to the directions provided, and jot down ideas as they come to you (and your group). Use these ideas to put together an answer to this question.

Check Check your answer with the one on page 24.

You have seen that there is a close association between climate conditions and living organisms. That makes it important that climate conditions be kept stable, don't you think? Would you want to be aware of any change occurring in Earth's climate? Have you read or heard about global warming? Why do scientists think it is happening? The next reading deals with these questions.

Turn to page 352 of the textbook and read "Climate Change." Then read "Interpreting Climate Data" on page 354.

6. Answer questions 6 and 8 of "Check and Reflect" on page 354 of the textbook.

Check Check your answers with those on pages 25 and 26.

You discovered that there is evidence indicating climate change. But is this change enough to affect living things in Canada? The next activity should give you more insight into this question.

Decision-Making Investigation

Climate Change Today

Read the entire activity on page 353 of the textbook.

Begin by reading "Background Information." This is to be an ongoing activity; continue with this module as you gradually build a collection of information. You may work on your own if you do not have a group to work with, and you may organize the information into folders for easy reference.

To start your research, visit the following website:

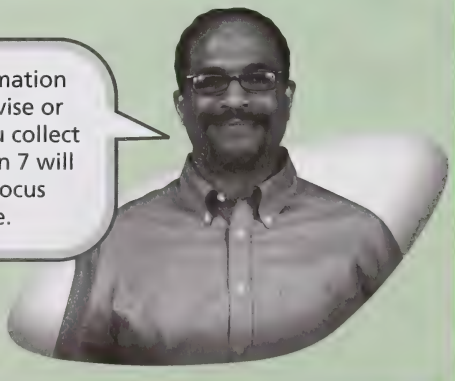
http://www.climatechange.gc.ca

Then use any of the Internet's search engines, such as Google, to continue your research. Use terms such as *global climate change* or *global warming* to help in your search. When you collect information, always consider the source.

To further your research, read several articles on climate change from newspapers and periodicals, such as the *Edmonton Journal*, *Calgary Herald*, *Red Deer Advocate*, *National Post*, *Time*, *Maclean's*, and *Newsweek*. Refer to your local library or the Internet for access to these publications.

7. Once you have collected some information, answer questions 1 and 2 of "Analyze and Evaluate." Set up your answers so you can revise them as you find additional information.

Check your answers with those on page 26.



Looking Back

You have completed all the concepts for this lesson. You described how climate affects living things and explained the need to investigate climate change.

8. Answer question 12 of "Section Review" on page 355 of the textbook.

Check your answers with those on page 26.

Go to pages 3 to 5 of Assignment Booklet 4A and answer questions 9 to 13.

Glossary

adaptation: any change in the structure or function of an organism that makes it more suited to its environment; the structure or function itself resulting from adaptation

anecdotal evidence: evidence that relies on reports from people about particular events and their interpretation of these events

climate change: a change that occurs in the climate of a region over a long period of time

scientific evidence: evidence collected in a manner that ensures it is unbiased and reflects general situations rather than particular events

Scientific evidence is usually collected by trained scientists and checked by other trained scientists.

Suggested Answers

1. The colder the climate, the lower the population density. For example, the population density of Alberta is 4.8 people per km^2; the population density of the Northwest Territories is only 0.036 people per km^2. The climate is much colder in the Northwest Territories. **Note:** In other parts of the world, the hottest climates may be considered to be the harsh climates (e.g., desert areas).

2. In some regions of California, houses have no furnaces because the climate is warm. A furnace requires a chimney to carry off smoke. Without a furnace, homes have no need for a chimney.

3. Fruit trees cannot survive extreme cold. The Okanagan Valley has a warm climate, whereas the climate in High Level is cold. Therefore, the Okanagan Valley is a better region for farmers to grow fruit than the region around High Level.

4. **Textbook question 2 of "Check and Reflect," p. 354**

   2. Answers will vary according to the organism chosen. A sample answer is given.

      A grizzly bear's behaviour changes according to the season. It is inactive in the winter and active in the summer. Its weight increases over the summer and decreases over the winter.

5. Answers may vary. Brainstorming will yield unique ideas, and predicting the effects of climate change is a difficult exercise. There are many variables to consider. A sample answer is given.

   The fur of an Arctic wolf is white and, thus, provides a camouflage against the snow. With an increase in temperature, a loss of snow cover will occur due to melting. Where there is no snow, the white Arctic wolf will be more conspicuous than the darker, common wolf. The common wolf will then out compete the Arctic wolf for prey where there is no snow. With the smaller area in which the Arctic wolf can move inconspicuously, it resides in a smaller habitat. With a smaller habitat, the population of the Arctic wolf may drop. On the other hand, with milder temperatures, more small prey may migrate north. This may increase the food supply for the Arctic wolf and negate some of the negative effects of reduced snow cover.

   With an increase in temperature, wetlands used by the trumpeter swan may dry up and disappear. However, wetlands may appear further north of the present wetlands used by the trumpeter swan. The new wetlands may also be further from human population centres. These more remote wetlands may be left undisturbed and, therefore, may better protect trumpeter cygnets (young swans). The net effect will be an increase in the trumpeter swan population.

   The purple lilac would bloom even earlier with an increase in temperature. This lilac would likely be able to live further north as well, where conditions once were too severe. Overall, the purple lilac would increase its range and increase its population.

6. **Textbook questions 6 and 8 of "Check and Reflect," p. 354**

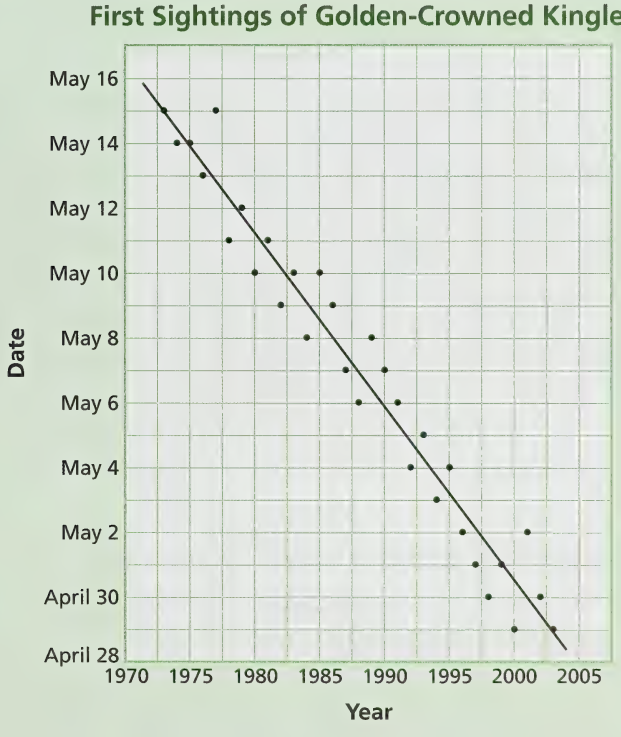
6. Answers will vary. Examples of anecdotal evidence of climate change are as follows:

- Farmers report that the growing season starts earlier every year.
- A resident of Nunavut states, "The elders in the olden days could predict the weather accurately. Nowadays, they can't. The weather is just too unpredictable. The climate, today, includes more extreme weather conditions."

Examples of scientific evidence of climate change are as follows:

- According to Environment Canada, the average temperature in Canada increased by 1.0°C from 1948 to 1999.
- According to researchers from the University of Alberta, the average flowering date of the trembling aspen in the spring moved 26 days earlier between 1901 and 1997. This date advanced from early May to early April.

8. a. Graphs may vary. A sample graph with a line of best fit is given.



b. There have been fluctuations in the date of the first sightings; but, overall, the first sighting of the golden-crowned kinglet has come earlier over the years.

c. The golden-crowned kinglet's migratory behaviour is likely triggered by spring weather conditions (in their more southerly range). According to the migratory behaviours shown in the graph, spring conditions, meaning a rise in average temperature, have come earlier. This is due to the climate warming over the 30-year period.

d. Additional information that could be collected as evidence to support the hypothesis are

- data based on tree rings that relate to the conditions of the growing season
- data indicating the first flowering of a plant, such as wild rose or tiger lily
- data of first spring sightings of other migratory birds
- weather data over the 30-year period

7. **Textbook questions 1 and 2 of "Analyze and Evaluate," p. 353**

Answers will vary according to how far along you are in your research and how you judge the magnitude of the effect. A sample answer is given.

1. The impact on the people in the Arctic has been the most severe. The ice season has become shorter and less reliable. This has made winter fishing and hunting more challenging, even dangerous.

2. In the St. Lawrence region, living things were most affected by climate change. Seal pups are born on the ice and must stay on the ice until they can swim. In 2002, the winter was so mild that sea ice was severely limited. As a result many seal pups were lost soon after birth.

8. **Textbook question 12 of "Section Review," p. 355**

12. The information about climate is classified as follows:

a. scientific evidence
b. anecdotal evidence
c. anecdotal evidence
d. scientific evidence

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Conclusion

In this section you described the atmosphere, the hydrosphere, and the lithosphere as components of the biosphere. You explained how climate keeps the biosphere suitable for life. You also examined evidence that the global climate may be changing.

One possible global climate change involves a worldwide rise in temperature. This change can have negative effects on all living things.

In Canada's North, for example, a worldwide rise in temperature can lead to a loss of sea ice. Seals and other northern wildlife need sea ice for breeding and feeding. A loss of sea ice could threaten the survival of many mammals in the North, such as the polar bear and the seal. Analyzing climate data may raise awareness of the risks to the well-being of living things in the future.

Energy Transfer in the Biosphere

Do you enjoy outdoor activities more on a sunny day than on a cloudy day? Most people do. A bright, sunshiny day seems to put people in a better frame of mind. It is the absorption of the radiant energy of the Sun that helps make the day warmer.

The absorption of the radiant energy provided by the Sun goes far beyond producing a fine day. The resulting thermal energy from the Sun transfers from one geographic region to another. This flow of energy generates a variety of climate conditions and biomes.

In this section you will identify the Sun as the source of the energy flowing through the biosphere. You will discover that variations in the absorption of solar energy around the globe leads to global energy transfer and various climate conditions. You will also investigate the connection between Earth's major biomes and their climate conditions.

Turn to page 356 of the textbook and read the introduction to Unit D 2.0. Read the key concepts and learning outcomes listed. They provide a brief overview of what you will cover in this section.

Lesson 1

Energy Relationships and the Biosphere

Have you visited a greenhouse on a sunny day? Even when the temperature is cold outside, the greenhouse can get very warm simply due to solar energy. Incoming solar energy is converted into thermal energy inside the greenhouse. The thermal energy is then trapped inside, heating up the room.

radiant energy: energy that is transmitted as electromagnetic waves

electromagnetic spectrum: the entire range of wavelengths of electromagnetic radiation extending from radio waves (longest) to the cosmic rays (shortest)

Earth, as a whole, is also kept warm by solar energy. What is the nature of solar energy? Solar energy is a form of **radiant energy**, like radio waves. Radio waves make up only part of the **electromagnetic spectrum**. Solar energy, which includes visible light, consists of radiant energy from the entire electromagnetic spectrum.

Turn to page 357 of the textbook and read the introductory paragraphs of "Energy Relationships and the Biosphere."

1. List the following forms of radiant energy from longest to shortest wavelengths.

   - visible light
   - radio waves
   - infrared light
   - ultraviolet
   - microwaves
   - cosmic rays

2. What is insolation?

Check your answers with those on page 39.

angle of inclination: the degree by which Earth's poles are tilted from the perpendicular of the plane of its orbit

Imagine going to Australia during your summer vacation. You would be visiting during Australia's winter. This is because Earth's **angle of inclination** causes seasonal changes in insolation in a given region. Australia's position on the other side of the equator results in having seasons opposite to those in Canada.

Find out more about the effects of the angle of inclination. Read "Insolation and the Angle of Inclination" on pages 357 to 359 of the textbook. Pay particular attention to Figure D2.4 on page 358. Note that Earth rotates around a line called the axis of rotation. This axis meets Earth's surface at the north and south poles.

3. Why is insolation in the Northern Hemisphere greatest on June 21–22?

4. How does the latitude affect the hours of daylight in the Northern Hemisphere at its summer solstice?

5. What is an equinox?

Check your answers with those on pages 39 and 40.

In the Northern Hemisphere, the region within the Arctic circle has 24 hours of sunlight during the summer solstice. Conversely, these regions have 24 hours of darkness during the winter solstice.

angle of incidence: the angle between a ray falling on a surface and the line of the perpendicular to that surface

Have you ever noticed that the snow often melts off a south-facing roof faster than off a north-facing one? Have you noticed a difference in shingle weathering on roof surfaces? Shingles seem to last longer on north-facing slopes where the Sun's radiation arrives at a greater **angle of incidence**.

Do you recall working with the angle of incidence in previous courses? The angle of incidence is measured from the perpendicular of a surface.

In the next activity you will investigate the relationship between the angle of incidence of radiant energy on a surface and the heating effect of the radiant energy.

Inquiry Lab

Angle of Incidence and Rate of Temperature Change

Read the entire activity on pages 360 and 361 of the textbook.

6. What are the manipulated and the responding variables?

7. Write a hypothesis for the investigation.

Check your answers with those on page 40.

If you have access to the materials and equipment listed, do **Part A**. If you do not have access to the materials and equipment listed, do **Part B**.

Part A

Follow the steps outlined in the procedure. As you change the angle of the paper pocket, move the support blocks as needed. You must maintain the 30-cm distance between the centre of the pocket and the lamp.

Pay special attention to the safety precautions mentioned.

8. Record your data in the following table.

Length of Exposure to Light (min)	Temperature of Probe (°C)		
	AI* = 0°	AI* = 45°	AI* = 90°
0			
1			
14			
15			

*AI: angle of incidence

9. Answer the following on pages 360 and 361 of the textbook.

   a. questions 2 and 3 of "Analyzing and Interpreting"
   b. questions 4 and 5 of "Forming Conclusions"
   c. question 6 of "Applying and Connecting"

Check your answers with those on pages 40 to 42.

Part B

Two Science 10 students completed Part A of this investigation. Their results are recorded in the following table. Use this information to answer question 9 in Part A.

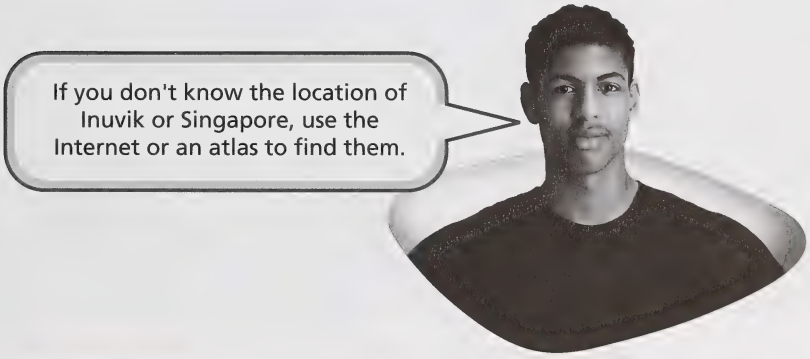
Length of Exposure to Light (min)	Temperature of Probe (°C)		
	AI* = 0°	AI* = 45°	AI* = 90°
0	21.0	21.0	21.0
1	25.0	22.6	21.0
2	26.5	23.8	21.0
3	28.0	24.5	21.0
4	29.0	25.0	21.0
5	30.0	25.5	21.2
6	31.0	26.0	21.2
7	32.0	26.5	21.4
8	32.5	27.0	21.5
9	33.0	27.3	21.5
10	33.5	27.5	21.5
11	34.0	27.8	21.5
12	34.5	28.0	21.8
13	34.5	28.0	21.8
14	35.0	28.5	22.0
15	35.0	29.0	22.0

*AI: angle of incidence

The results of the preceding investigation showed the relation between the angle of incidence of radiant energy on a surface and the heating effect of the radiant energy. This relation applies to the differing rates of snow melting from roof tops. More significantly, it applies to the differing rates of solar energy absorbed by Earth's spherical surface.

Turn to pages 359 and 361 of the textbook and read "Insolation and the Angle of Incidence."

10. For Inuvik, Northwest Territories, the average temperature for the year is only $-9°C$. For Singapore, the average temperature is about $27°C$. Explain why there is such a difference in average temperature.



Check your answer with the one on page 42.

Latitude is not the only factor affecting the amount of solar energy absorbed. There are other factors.

Turn to pages 362 and 363 of the textbook and read "Absorption and Reflection by the Biosphere" and "Albedo—Reflection by the Lithosphere and Hydrosphere."

11. Radiant energy can be reflected or absorbed by a substance. Which causes a rise in temperature—reflection or absorption?

12. What is the percent of solar radiation reflected by a surface called?

13. Answer questions 2 and 8 of "Check and Reflect" on page 369 of the textbook.

Check your answers with those on page 42.

Any warm surface emits radiant energy. In particular, a surface warmed by solar energy emits radiant energy, or rather, re-emits radiant energy. This re-emitted radiant energy is in the form of infrared radiation—a longer wavelength than much of the incoming solar energy. This re-emission would represent a complete loss of thermal energy except for one factor—the presence of the atmosphere. The atmosphere functions somewhat like the glass in a greenhouse in containing thermal energy.

Turn to page 365 of the textbook and read "Natural Greenhouse Effect."

14. What is the natural greenhouse effect?

15. Which **greenhouse gas** is the main contributor to the natural greenhouse effect?

greenhouse gas: a gas that absorbs infrared radiation released from Earth's surface

Check your answers with those on page 42.

Have you ever saved up for something? If your savings are to grow, you need to keep to a budget. Without controls on your spending, you may never reach your financial goals.

net radiation budget: the difference between the amount of incoming radiation and outgoing radiation from Earth's surface and atmosphere

Although the **net radiation budget** is not directly related to your bank balance, this budget is very important.

Earth's Radiation Budget

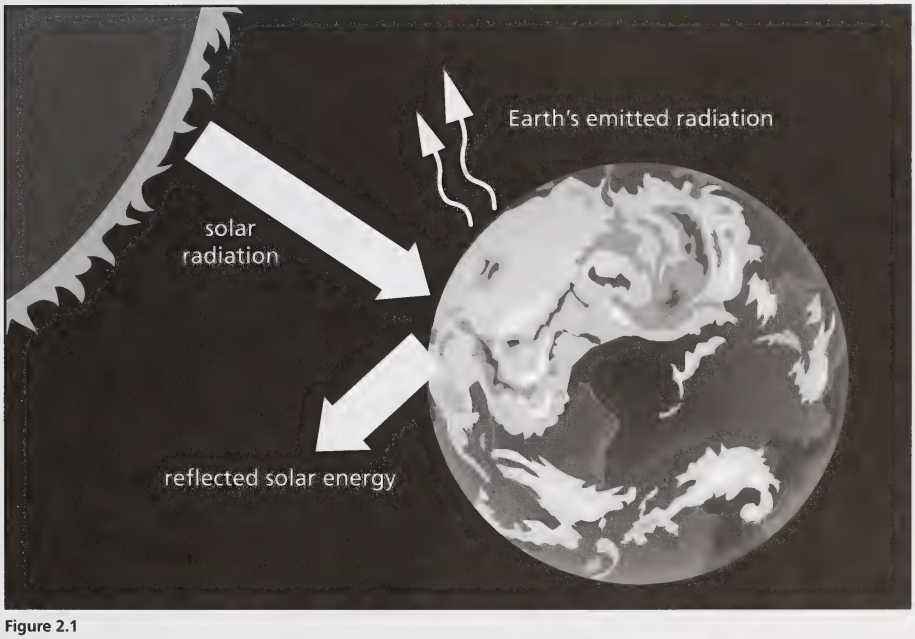


Figure 2.1

Solar radiation is partially reflected and partially absorbed by Earth's surface, clouds, and atmosphere. Solar radiation that is reflected goes back into space without a change in wavelength. Only the solar radiation that is absorbed is considered to be incoming radiation. The outgoing radiation is the infrared radiation emitted by the Earth-atmosphere system. The net radiation budget describes the relation between incoming radiation and outgoing radiation.

The following diagram shows the net radiation budget in more detail.

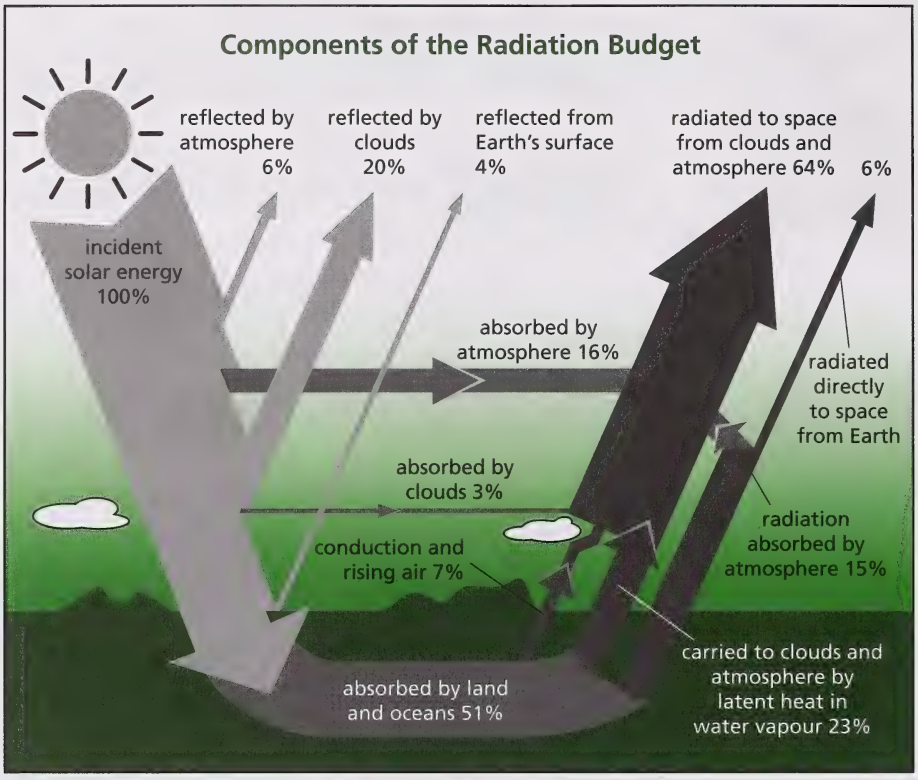
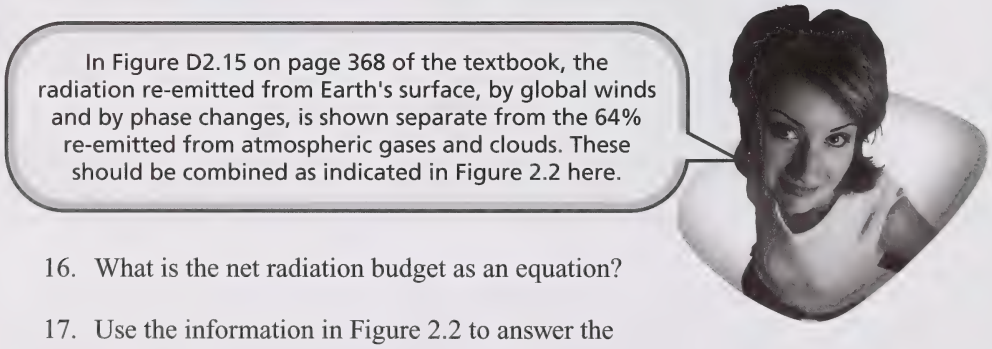


Figure 2.2

Turn to pages 367 and 368 of the textbook and read "Net Radiation Budget." For now, read only up to "Net Radiation Budget and Latitude" on page 368.



16. What is the net radiation budget as an equation?

17. Use the information in Figure 2.2 to answer the following.

    a. What percent of the incident solar energy is reflected?

    b. What percent of the incident solar energy is actually incoming energy for Earth's net radiation budget?

c. What percent of the incident solar energy is re-emitted to space by clouds and the atmosphere?

d. What percent is re-emitted directly from Earth's surface to space?

e. Evaluate the net energy radiation by substituting percent values into its word equation.

f. Draw a pie graph showing what happens to the incident solar energy on Earth. Show the percent of incident solar energy reflected into space, the percent absorbed by clouds and the atmosphere, and the percent absorbed by land and oceans.

Check your answers with those on pages 42 and 43.

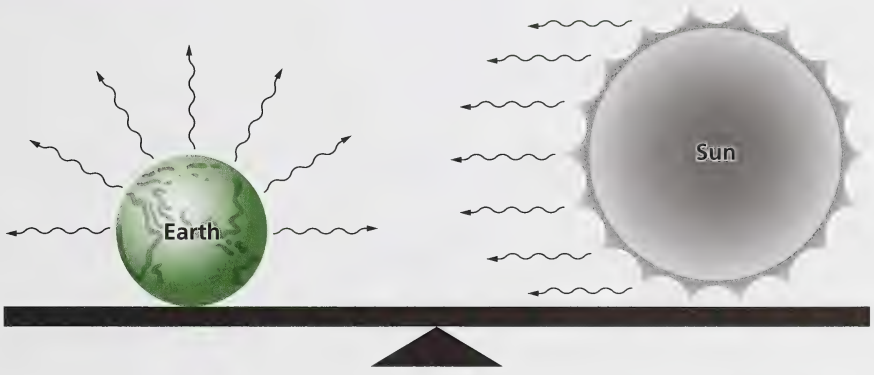


Figure 2.3

Although the entire Earth's net radiation budget is balanced, the net radiation budget for many regions is unbalanced.

Now, read "Net Radiation Budget and Latitude" on pages 368 and 369 of the textbook. Examine Figure D2.16 closely.

18. The regional imbalance in solar radiation is graphed in Figure D2.16 on page 368 of the textbook.

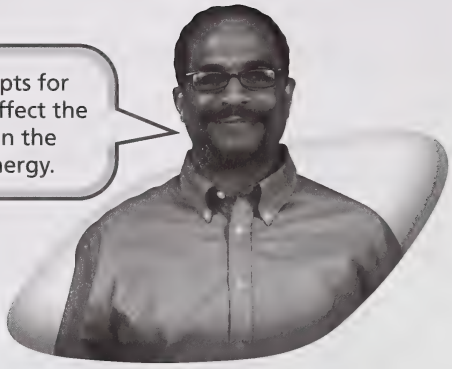
    a. Between which latitudes is there a radiation deficit?

    b. Between which latitudes is there a radiation surplus?

    c. Explain why the temperature would not drop where there is a radiation deficit and rise where there is a radiation surplus.

Check your answers with those on page 43.

Looking Back



You have just completed all the concepts for this lesson. You described factors that affect the amount of solar radiation absorbed in the biosphere and retained as thermal energy.

19. Match each definition with its corresponding term in the following list.

i. angle of inclination	ii. equinox
iii. greenhouse gases	iv. insolation
v. latitude	vi. natural greenhouse effect
vii. net radiation budget	viii. solstice

a. gases that absorb infrared radiation released from Earth's surface

b. one of two points in Earth's orbit at which the number of daylight hours anywhere on Earth's surface is equal to the number of hours of night

c. one of two points in Earth's orbit at which the poles are most tilted toward or away from the Sun

d. the absorption of radiant energy by the atmosphere

e. the amount of solar energy received by a region of Earth's surface

f. the angular distance of a line north or south of the equator measured in degrees

g. the degree by which the Earth's poles are tilted from the perpendicular of the plane of its orbit

h. the difference between the amount of incoming radiation and outgoing radiation from Earth's surface and atmosphere

20. Answer question 12 of "Check and Reflect" on page 369 of the textbook.

Check your answers with those on pages 43 and 44.

Go to pages 1 to 5 of Assignment Booklet 4B and answer questions 1 to 14.

Glossary

absorb: to convert radiant energy into a form of energy associated with a rise in temperature

When a substance absorbs radiant energy, the kinetic energy of its particles increases.

albedo: the percent of incident solar energy a surface reflects

angle of incidence: the angle between a ray falling on a surface and the line of the perpendicular to that surface

angle of inclination: the degree by which Earth's poles are tilted from the perpendicular of the plane of its orbit

Earth's angle of inclination is 23.5°.

electromagnetic spectrum: the entire range of wavelengths of electromagnetic radiation extending from radio waves (longest) to cosmic waves (shortest)

equinox: one of two points in Earth's orbit at which the number of daylight hours anywhere on Earth's surface is equal to the number of hours of night

greenhouse gas: a gas that absorbs infrared radiation released from Earth's surface

Greenhouse gases contribute to the greenhouse effect.

incident: falling on or striking a surface

insolation: the amount of solar energy received by a region of Earth's surface

latitude: the imaginary lines that run parallel to Earth's equator; the angular distance of a line of latitude north or south of Earth's equator measured from 0° through 90°

natural greenhouse effect: the absorption of radiant energy by the atmosphere

net radiation budget: the difference between the amount of incoming radiation and outgoing radiation from Earth's surface and atmosphere

radiant energy: energy that is transmitted as electromagnetic waves

reflect: to change the direction of an incident ray as it comes back from a surface

solstice: one of two points in Earth's orbit at which the poles are most tilted toward or away from the Sun

Suggested Answers

1. radio waves, microwaves, infrared light, visible light, ultraviolet, cosmic rays

2. Insolation (not insulation) is the amount of solar energy received by a region of Earth's surface.

3. Insolation in the Northern Hemisphere is greatest on June 21–22 because it is the summer solstice. At that time, the Northern Hemisphere is tilted the greatest amount towards the Sun—the days have the maximum number of hours of sunlight.

4. The greater the latitude, the greater the number of hours of daylight at its summer solstice.

5. An equinox is a point in Earth's orbit at which the number of daylight hours anywhere on Earth's surface is equal to the number of hours of darkness. There are only two equinoxes in Earth's orbit. Each year, one occurs on March 21–22 and the other occurs on September 22–23.

6. The manipulated variable is the angle of incidence, and the responding variable is the temperature of pocket.

7. Hypotheses may vary. A sample hypothesis is given.

   The greater the angle of incidence, the lower the temperature of the pocket. This is because the pocket absorbs less light at higher angles of incidence.

8. Data will vary. Sample data is given.

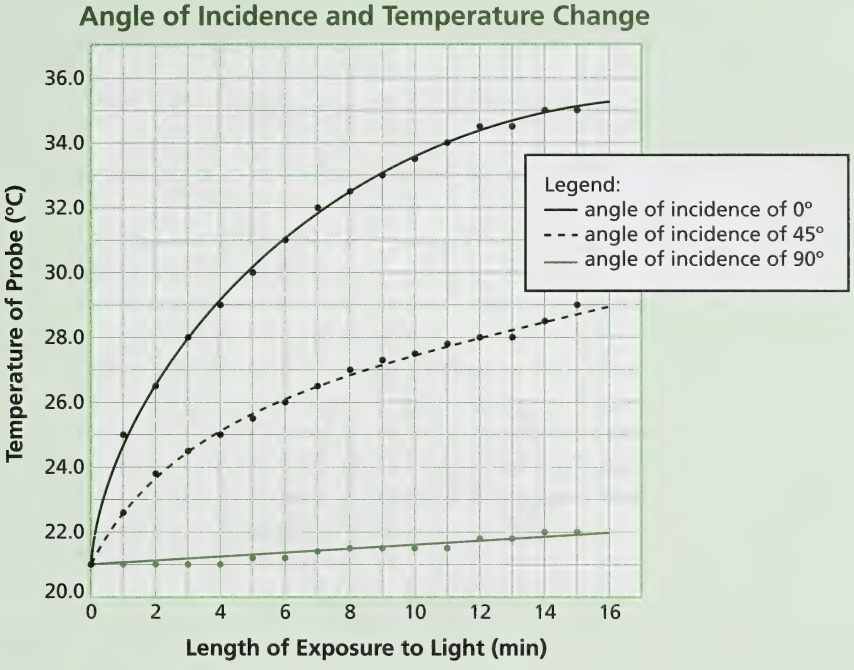
Length of Exposure to Light (min)	Temperature of Probe (°C)		
	AI* = 0°	AI* = 45°	AI* = 90°
0	21.0	21.0	21.0
1	25.0	22.6	21.0
2	26.5	23.8	21.0
3	28.0	24.5	21.0
4	29.0	25.0	21.0
5	30.0	25.5	21.2
6	31.0	26.0	21.2
7	32.0	26.5	21.4
8	32.5	27.0	21.5
9	33.0	27.3	21.5
10	33.5	27.5	21.5
11	34.0	27.8	21.5
12	34.5	28.0	21.8
13	34.5	28.0	21.8
14	35.0	28.5	22.0
15	35.0	29.0	22.0

*AI: angle of incidence

9. a. **Textbook questions 2 and 3 of "Analyzing and Interpreting," p. 360**

2. Variables that were held constant were the type and wattage of the lamp, the distance between the pocket and the lamp, the time over which the pocket was exposed to the light, and the ambient temperature.

3. Your graph should be similar to the following.



b. **Textbook questions 4 and 5 of "Forming Conclusions," p. 361**

4. As the angle of incidence increases, the rate of temperature change decreases.

5. The angle of incidence of 0° exposed the pocket to the greatest amount of radiant energy. At this angle, the heating of the pocket was the greatest. The angle of incidence of 90° exposed the pocket to the least amount of radiant energy. At this angle, the heating of the pocket was the least.

c. **Textbook question 6 of "Applying and Connecting," p. 361**

6. The angle of incidence of solar radiation on the globe increases with latitude. Therefore, the insolation decreases with latitude. As latitude increases, the average temperature should decrease.

> **Note:** Figure D2.5 on page 359 of the textbook shows how the angle of incidence decreases as you move towards the polar region. It also shows how a beam of light is spread over a greater area in the polar region.
>
> Figure D2.8 on page 361 of the textbook indicates the temperatures for an Arctic location and one near the equator. The graphs show that the average temperature in the Arctic is indeed lower than near the equator.

10. Inuvik is at latitude of 68°. Singapore is at latitude of 1°. This difference in latitude results in a wide variation in insolation—Inuvik receives far less solar energy than Singapore. Therefore, Inuvik is much colder than Singapore on average.

11. Absorption of radiant energy causes a rise in temperature.

12. The percent of solar radiation reflected by a surface is called albedo.

13. **Textbook questions 2 and 8 of "Check and Reflect," p. 369**

    2. Cloud cover reflects and absorbs solar radiation. In this way, clouds reduce the amount of solar radiation reaching Earth's surface.

    8. The albedo of an area covered with snow is greater than one covered with dark soil.

14. The natural greenhouse effect is the absorption of thermal energy by the atmosphere.

15. Water vapour is the main contributor to the natural greenhouse effect.

16. net radiation budget = incoming radiation – outgoing radiation

17. a. 30% of the incident solar energy is reflected.

    b. 70% of the incident solar energy is absorbed. Therefore, 70% of the incident solar energy is incoming energy.

    c. 64% of the incident solar energy is re-emitted to space by clouds and the atmosphere.

    d. 6% is re-emitted directly from Earth's surface.

e. The outgoing radiation is the sum of the amount of radiation re-emitted from the clouds and atmosphere and the amount re-emitted directly from Earth's surface.

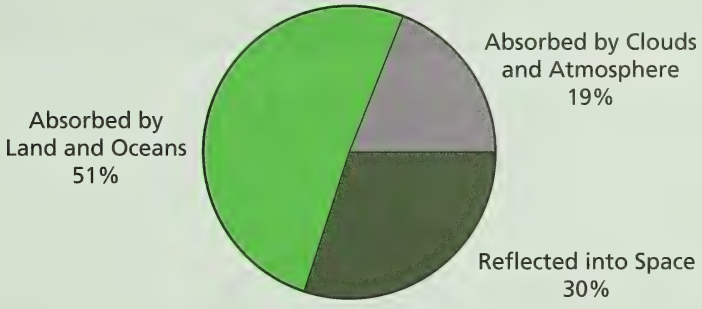
$$\begin{aligned}\text{net radiation budget} &= \text{incoming radiation} - \text{outgoing radiation} \\ &= 70\% \text{ of the incident solar energy} - (64\% + 6\%) \text{ of the incident solar energy} \\ &= 70\% - 70\% \\ &= 0\%\end{aligned}$$

The net radiation budget is zero according to the diagram.

Note: The net radiation budget is in reality not precisely zero. Otherwise, scientists would not be finding that there has been a recent rise in the global temperature. You will study global warming in more detail later in this module.

f. Your pie graph should be similar to the following.

Distribution of Incident Solar Energy on Earth



18. a. There is a radiation deficit between 40°N and 90°N latitude and between 40°S and 90°S latitude.

b. There is a radiation surplus between 40°N and 40°S latitude.

c. Thermal energy transfers from a region of radiation surplus to a region of radiation deficit. This transfer keeps the temperatures stable over time.

Note: Generally, it's warmer where there is a radiation surplus and cooler where there is a radiation deficit. This question is not about why there is a temperature difference between regions. It is about why the temperatures do not vary over time.

19. a. iii b. ii c. viii d. vi e. iv f. v g. i h. vii

20. **Textbook question 12 of "Check and Reflect," p. 369**

    12. The amount of radiation that reaches a region of Earth's surface is affected by cloud cover, atmospheric dust, and the latitude of the region.

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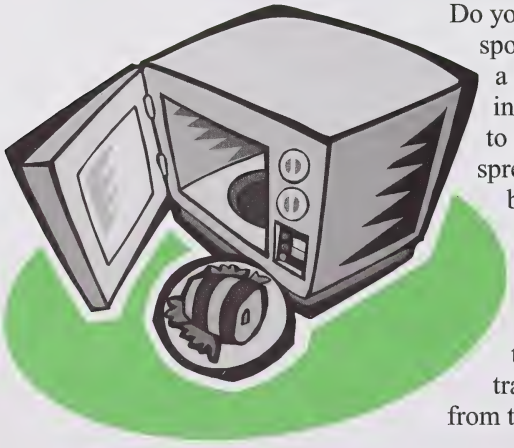
Lesson 2

Thermal Energy Transfer in the Atmosphere



Do you ever find hot spots and cold spots in food you've just heated in a microwave? After heating food in a microwave, usually you have to wait for the thermal energy to spread evenly throughout the food before eating it. Regions in food where microwave radiant energy is absorbed more so than in other regions become hotter. The spreading of thermal energy throughout the food involves the transfer of thermal energy away from these hot spots.

conduction: the transfer of thermal energy by direct contact between the particles of a substance, without moving the particles to a new location

convection: the transfer of thermal energy through the movement of particles from one location to another

radiation: the emission of energy as radiant energy

A transfer of thermal energy also occurs in Earth's atmosphere. In the atmosphere, this transfer is due to the uneven absorption of solar radiation.

Do you remember from previous science courses the different ways to transfer thermal energy? The next reading may refresh your memory about **conduction**, **convection**, and **radiation**.

Turn to page 370 of the textbook and read the introduction to "Thermal Energy Transfer in the Atmosphere." Then continue by reading "Conduction and Convection" on pages 370 and 371.

1. Why is thermal energy transfer important in keeping a person cool?

2. List the three methods of energy transfer by which hot objects lose energy to their surroundings.

3. For each of the following, state whether the description refers to conduction, convection, or radiation.

   a. involves currents
   b. involves electromagnetic waves
   c. is due to differences in density
   d. requires direct contact
   e. usually takes place in fluids, not solids

Check your answers with those on page 48.

atmospheric pressure: the pressure exerted by the mass of air above any point on Earth's surface

wind: the movement of cool air from an area of high atmospheric pressure to an area of low atmospheric pressure

A light wind on a summer's day may be welcome for its cooling effect. In winter, the wind chill may be unpleasant. Wind is a major factor in thermal energy transfer in the atmosphere. Wind affects your daily living; it also affects climates and events around the globe.

Differences in **atmospheric pressure** in neighbouring regions on Earth's surface lead to **wind**.

Turn to pages 372 and 373 of the textbook and read "Effects of Thermal Energy Transfer in the Atmosphere." Examine Figures D2.20 and D2.21 closely.

4. In which direction does air move with regards to pressure areas?

5. Why does an area of high pressure form where the air is cold?

6. Earth's rotation deflects airflow from a direct north-south direction. What is this deflection called?

Check your answers with those on page 48.

Quicklab

The Coriolis Effect

Read the entire activity on page 373 of the textbook.

Coriolis effect: the deflection of any object from a straight-line path by Earth's rotation

Follow the steps outlined in the procedure. You will need to ask someone to help you. For step 3, draw a counterclockwise arrow to represent the actual direction of Earth's rotation (as seen from above the North Pole). Therefore, in step 4, rotate the cardboard disk counterclockwise while drawing your straight line.

Be very careful when cutting out your cardboard circle.

7. Answer questions 1, 2, and 3 of "Questions."

Check your answers with those on pages 48 and 49.

Going Further

You can see a Coriolis-like effect on a rotating merry-go-round at the following website:

http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/fw/crls.rxml

Click on the movie link at the bottom of the page. In this movie, the ball starts at the edge rather than at the centre. When the camera is on the merry-go-round, you are using the merry-go-round as the frame of reference rather than the ground. The merry-go-round models Earth's rotation as seen from above the South Pole.

Living in Alberta, you probably notice that wind most often comes from the west. That is because Alberta is in the temperate zone where west-to-east winds blow. These winds, called prevailing westerlies, contribute to global wind patterns.

jet stream: a band of fast-moving air in the stratosphere

The Coriolis effect is an important factor responsible for global wind patterns, and it also directs the path of **jet streams**.

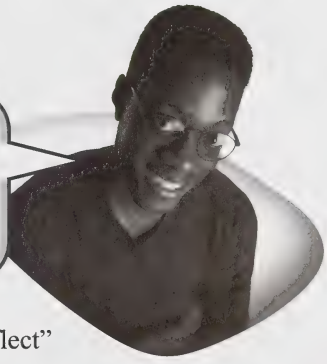
Turn to pages 374 and 375 of the textbook and read "Global Wind Patterns."

8. Answer questions 6, 8, 9, and 10 of "Check and Reflect" on page 375 of the textbook.

Check Check your answers with those on page 49.

Looking Back

You have now completed the concepts for this lesson. You investigated the movement of thermal energy in the atmosphere between regions of high temperatures and regions of low temperatures.



9. Answer questions 16 and 17 of "Check and Reflect" on page 375 of the textbook.

Check Check your answers with those on page 49.

Go to ... Go to pages 6 and 7 of Assignment Booklet 4B and answer questions 15 to 19.

Glossary

atmospheric pressure: the pressure exerted by the mass of air above any point on Earth's surface

conduction: the transfer of thermal energy by direct contact between the particles of a substance, without moving the particles to a new location

convection: the transfer of thermal energy through the movement of particles from one location to another

Coriolis effect: the deflection of any object from a straight-line path by Earth's rotation

current: flow from one place to another in one direction

density: mass per volume of a substance

fluid: any substance that has no definite shape and tends to flow

Gases and liquids are fluids.

jet stream: a band of fast-moving air in the stratosphere

radiation: the emission of energy as radiant energy

wind: the movement of cool air from an area of high atmospheric pressure to an area of low atmospheric pressure

Suggested Answers

1. A person produces 100 J of thermal energy every second. Without thermal energy transfer, a person's temperature would rise to levels that would be lethal.

2. The three methods of energy transfer are conduction, convection, and radiation.

3. a. convection b. radiation c. convection d. conduction e. convection

4. Air moves from a high-pressure area to a low-pressure area.

5. When air cools, it contracts and becomes more dense. A column of more dense air exerts more pressure and, thus, forms an area of high pressure.

6. The deflection of airflow due to Earth's rotation is called the Coriolis effect.

7. **Textbook questions 1, 2, and 3 of "Questions," p. 373**

    1. The line twists towards the west. **Note:** If you draw a straight line slow enough over the rotating cardboard disk, you will see a line winding around the North Pole in a clockwise direction.

2. The twisting line represents the deflection from a direct north-south line of the wind moving from the polar region.

3. The rotation of the disk represents Earth's rotation as it appears from space above the North Pole. The movement of the pen is like the movement of the wind as viewed from space above the pole. The track of the pen is the actual path of the wind as it would be tracked on Earth's surface.

8. **Textbook questions 6, 8, 9, and 10 of "Check and Reflect," p. 375**

   6. The Coriolis effect is the deflection of an object's path due to Earth's rotation.

   8. The trade winds are global winds that blow westward (from the east to the west) and towards the equator. These winds occur in regions near the equator.

   9. Jet streams are bands of fast-moving air in the stratosphere.

   10. Jet streams occur at high altitudes where there is less friction to slow them down.

9. **Textbook questions 16 and 17 of "Check and Reflect," p. 375**

   16. The global wind patterns of the discovered planet would differ as follows:

   - The Coriolis effect would not deflect the global winds. Therefore, the global winds would generally blow in a straight north-south direction.

   - There wouldn't be the three giant cells of convection in each hemisphere. There would only be one cell in which the wind along the planet's surface would travel directly from the polar regions to the equator.

> **Note:** By comparing Figure D2.20 on page 372 of the textbook and Figure D2.22 on page 374, you can infer that the rotation of Earth is responsible for there being three convection cells in each hemisphere, rather than only one. The role of the Coriolis effect in maintaining these convection cells goes beyond the scope of Science 10.

   17. Sailing ships were propelled by wind. By following a more southerly route to South America, sailing ships caught the westward blowing trade winds to push them across the Atlantic. The return trip to Europe was made further north where the eastward blowing westerlies pushed them back across the Atlantic.

> **Note:** Winds are named by the direction they come from, not the direction in which they blow. For example, a west wind blows towards the east. A north wind blows towards the south.

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Lesson 3

Thermal Energy Transfer in the Hydrosphere

Every year, Calgary hosts a winter carnival where you can see really "cool" ice sculptures. During Calgary's winter, ice sculptures are usually able to remain frozen. Meanwhile, only approximately 1000 km away, Vancouver's winters are mild—too mild to maintain ice sculptures over weeks at a time.

Vancouver's winters are mild, especially compared to the prairie cities, due to thermal energy carried by a warm ocean currents flowing past the west coast. Ocean currents carry much of the thermal energy transferred by the hydrosphere. These transfers of thermal energy have a profound effect on climate around the globe.

Turn to page 376 of the textbook and read the introduction to "Thermal Energy Transfer in the Hydrosphere." Also, read "*info*BIT" for a little information about El Niño.

1. Name two factors that change the direction of ocean currents.

2. In the northern hemisphere, ocean currents that flow north tend to be warm currents and those that flow south tend to be cold currents. Give a reason for this.

3. In which hemisphere do ocean currents flow clockwise? In which hemisphere do they flow counterclockwise?

4. Name the regularly occurring disruption of ocean currents in the tropical Pacific that is linked to severe weather and climate events around the globe.

Check Check your answers with those on page 63.

specific heat capacity: the amount of energy needed to raise the temperature of 1 g of a substance 1°C

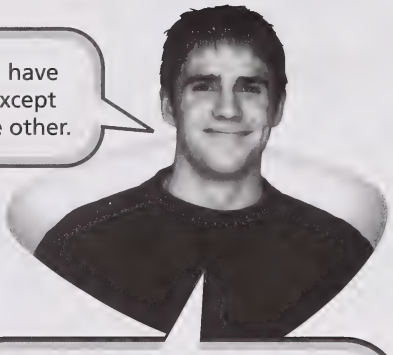
The **specific heat capacity** of water is high compared to other common fluids. This characteristic of water makes it suitable in hot-water heating systems, in the cooling systems of automobiles, and in Candu nuclear reactors. In each of these applications, water is used to carry thermal energy.

Because of water's high specific heat capacity, ocean currents and large bodies of water have much power over climate.

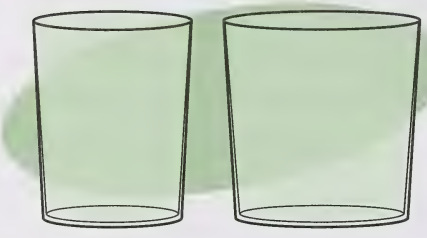
Read "Specific Heat Capacity" on pages 377 and 378 of the textbook to learn more about how large bodies of water can affect climate.

It's strange that the material with the greatest specific heat capacity changes temperature the least amount. I find that hard to believe.

Well then, suppose you have two identical glasses, except one is narrower than the other.



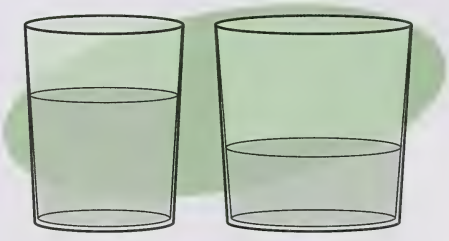
Empty Glasses

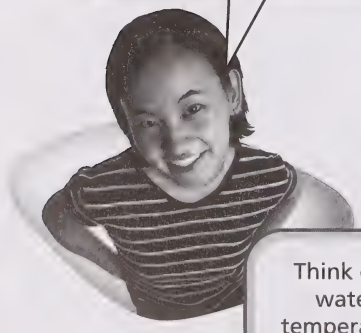


The capacity of the wider glass is much more than the narrower glass. Now, if you add the same amount of water to each glass, which glass will show the greater amount of change in the height of the water?

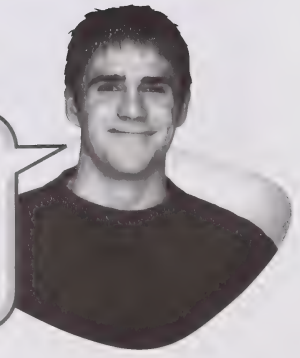
The height will change the least in the wider glass . . . I see. That's also the glass that can hold the most water; it's the glass with the greater water capacity.

Glasses Containing 200 mL of Water





Think of the change in height of the water in the glass as a change in temperature, and think of the capacity for water as specific heat capacity. The greater the specific heat capacity, the smaller the temperature change.



5. Samples of mercury, oil, and water are placed in separate beakers. The samples are at room temperature and have the same mass. The beakers are then placed in a warm-water bath for several minutes.

   Use the following table to determine which sample will experience the greatest temperature change and which will experience the smallest temperature change. Explain your answer.

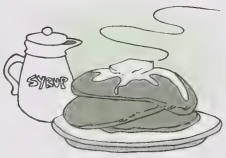
SPECIFIC HEAT CAPACITIES OF SOME LIQUIDS

Substance	Specific Heat Capacity c (J/g•°C)
mercury	0.139
oil	2.00
water	4.19

6. Explain why the air temperature varies over the seasons more in Lethbridge than in Vancouver.

Check your answers with those on pages 63 and 64.

Vancouver Skyline



Did you know that the unit joule can be used to indicate the energy of foods? Many people enjoy having pancakes served with maple syrup. Reading the label on the syrup bottle, you'll find that one 50-mL serving of syrup contains about 700 kJ of energy.

quantity of thermal energy: the amount of thermal energy absorbed or released when the temperature of a specific mass of a substance changes by a certain number of degrees

In earlier science modules you used formulas to calculate the number of joules of work done and the amount of electrical energy used. The next reading shows how to calculate the number of joules of thermal energy involved in a temperature change. In other words, you will calculate the **quantity of thermal energy**, Q.

$$Q = mc\Delta t$$

Read "Quantity of Thermal Energy, Q " on pages 378 to 380 of the textbook. Work through Example Problems D2.1 to D2.4 carefully. They show how to apply the formula for quantity of thermal energy in various forms. You will solve for Q, Δt, and c.

In your textbook, Δt is the absolute value of the temperature change—it's always positive. This is shown in Example Problem D2.2 on page 379. For this course, follow the same convention. Other textbooks may consider Δt to be negative when the temperature decreases and positive when the temperature increases.

7. Answer questions 1, 3, 4, 6, and 8 of "Practice Problems" on pages 379 and 380 of the textbook.

When solving a calculation problem, there are known values—values obtained from the information provided—and an unknown value—the one you need to determine for your final answer. You may find it helpful to start your solutions by listing both the known values and the unknown value.

Check your answers with those on pages 64 and 65.

With the specific heat capacity of water established, the specific heat capacity of other substances can be found by placing them in a calorimeter along with water. The next activity shows how to find the specific heat capacity for iron and copper. It also shows how temperature change and specific heat capacity are related.

Inquiry Lab

Investigating Specific Heat Capacity

Read the entire activity on pages 381 and 382 of the textbook.

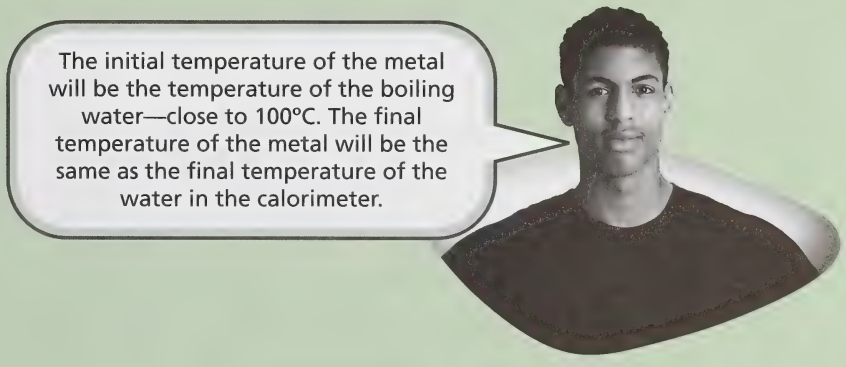
If you have access to a supervised laboratory, do **Part A**. If you do not have access to a supervised laboratory, do **Part B**.

Part A

Carefully follow the steps outlined in the procedure. Record your data as you move through the step in the table given in question 8.

Pay special attention to the safety precautions mentioned.

If a significant amount of thermal energy escapes from the calorimeter, then the amount of thermal energy gained by the water is less than the thermal energy lost by the metal. Therefore, a thermal energy loss can interfere with your experimental result for the specific heat capacity, c, of the metal.



8. Record your data in the following table.

Type of Metal	iron	copper
Mass of Metal		
Initial Temperature of Metal		
Final Temperature of Metal		
Mass of Calorimeter		
Mass of Water and Calorimeter		
Mass of Water in Calorimeter		
Initial Temperature of Water		
Final Temperature of Water		

9. Answer the following on pages 381 and 382 of the textbook.

   a. questions 1 to 6 of "Analyzing and Interpreting"
   b. questions 8 and 9 of "Forming Conclusions"

Check your answers with those on pages 65 to 67.

Part B

Two students completed this activity in a supervised laboratory at school. Their data is summarized in the following table. Use this data to answer question 9 in Part A.

Type of Metal	iron	copper
Mass of Metal	80.0 g	90.0 g
Initial Temperature of Metal	99.1°C	98.9°C
Final Temperature of Metal	33.7°C	33.3°C
Mass of Calorimeter	1.0 g	0.9 g
Mass of Water and Calorimeter	51.0 g	51.5 g
Mass of Water in Calorimeter	50.0 g	50.6 g
Initial Temperature of Water	22.5°C	22.5°C
Final Temperature of Water	33.7°C	33.3°C

phase: the state of a substance (solid, liquid, or gas)

You can be badly scalded by steam from water boiling in a kettle. When steam condenses, it changes from a gaseous **phase** to a liquid phase. In such a phase change, steam releases a great deal of thermal energy. It is the thermal energy released as steam condenses on your skin that is so damaging.

When you perspire, water evaporates from your skin and leaves in the gas phase. In evaporation, a substantial amount of thermal energy is absorbed from you skin. This absorption provides you with a cooling effect. Whenever water changes phase, thermal energy is either released or absorbed.

hydrologic cycle: the process by which water molecules move from Earth's surface into the atmosphere and then back again; also called the water cycle

In the **hydrologic cycle**, water goes through different phases. Because of these phase changes, the hydrologic cycle moves not only lots of water, but it moves vast amounts of thermal energy.

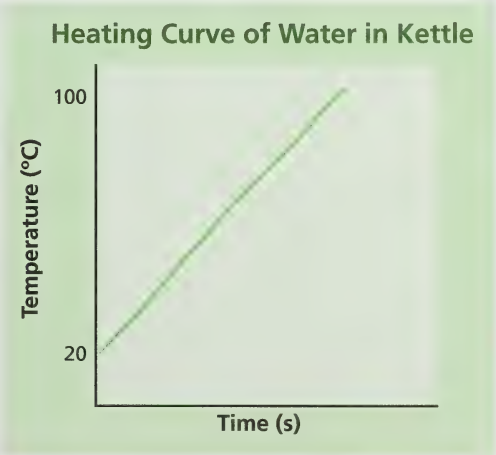
Read "The Hydrologic Cycle and Energy Transfer " on pages 382 and 383 of the textbook.

10. Answer questions 2 and 3 of "Check and Reflect" on page 390 of the textbook.

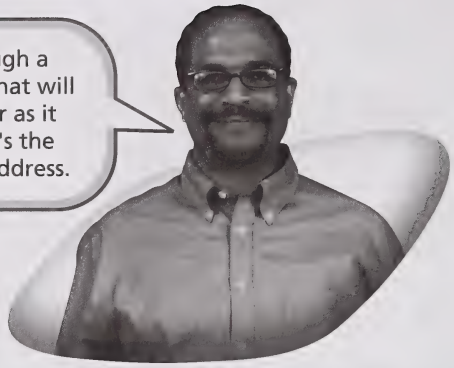
11. Explain why the temperature does not increase as thermal energy is absorbed during a phase change of water.

Check your answers with those on page 68.

When you heat up a kettle of fresh water, the water temperature goes up while the thermal energy from the heating element is absorbed. Initially, the temperature goes up at a fairly constant rate (linearly) with respect to time (as shown in the graph on the right).

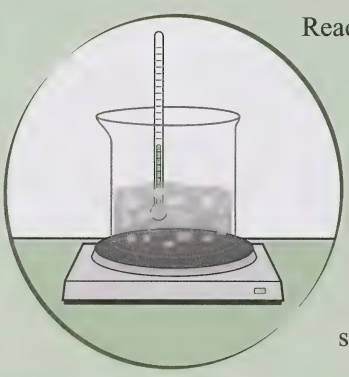


Water in a kettle does not go through a phase change until it starts to boil. What will the heating curve look like for water as it goes through a phase change? That's the question the next investigation will address.



Quicklab

Temperature and Phase Change



Read the entire activity on page 384 of the textbook.

You will base your investigation on the temperature change of an ice-water mixture rather than just "dry" crushed ice. Just enough water should be added to a half beaker of crushed ice to produce a slurry.

If you have access to a supervised laboratory, do **Part A**. If you do not have access to a supervised laboratory, do **Part B**.

Part A

Follow the steps outlined in the procedure. **Pay special attention to the safety precautions mentioned.**

12. Record your data in a table like the one on page 384 of the textbook.

13. Answer questions 1 to 4 of "Questions."

Check Check your answers with those on pages 69 and 70.

Part B

Use the following data of the heating of ice water to answer question 13 in Part A.

Time (s)	Temperature (°C)	Time (s)	Temperature (°C)
0	0.0	330	60.0
30	0.0	360	70.5
60	0.0	390	79.5
90	0.0	420	90.0
120	0.5	450	98.5
150	1.0	480	98.5
180	9.5	510	99.0
210	20.5	540	98.5
240	29.5	570	99.0
270	40.5	600	99.0
300	51.0		

As discovered in this QuickLab activity, a certain amount of thermal energy is either absorbed or released during phase changes.

The constants **heat of fusion** and **heat of vaporization** give an indication of the quantities of thermal energy involved in phase changes.

Turn to pages 383 to 385 of the textbook and read "Heat of Fusion and Heat of Vaporization." You will discover how these quantities relate to the heating curve of water.

heat of fusion: the amount of energy absorbed when 1 mol of a substance changes from the solid phase to the liquid phase without a change in temperature

heat of vaporization: the amount of energy absorbed when 1 mol of a substance changes from the liquid phase to the vapour phase without a change in

Continue by reading "Calculating Heat of Fusion and Heat of Vaporization" on pages 385 to 387 of the textbook. Work through Example Problems D2.5, D2.6, and D2.7 carefully. These practice problems show how and when to use the formulas for heat of fusion and heat of vaporization.

$$H_{\text{fus}} = \frac{Q}{n} \qquad H_{\text{vap}} = \frac{Q}{n}$$

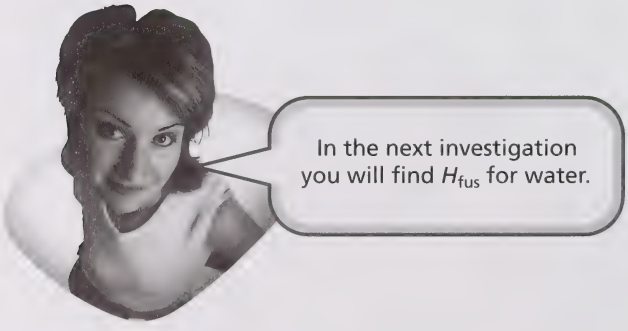
14. Answer question 11 of "Check and Reflect" on page 390 of the textbook.

15. The specific heat capacity, heat of fusion, and heat of vaporization are each based on a certain quantity of a substance.

    a. Which is/are expressed using the mass of the substance in grams?
    b. Which is/are expressed using the amount of the substance in moles?

16. Answer questions 10, 12, 14, and 15 of "Practice Problems" on pages 386 and 387 of the textbook.

Check your answers with those on pages 70 and 71.



Inquiry Lab

Thermal Energy and Melting Ice

Read the entire activity on page 388 of the textbook.

If you have access to the materials and equipment listed, do **Part A**. If you do not have access to the materials and equipment listed, do **Part B**.

Part A

Working with a partner, follow the steps outlined in the procedure. Record your data as directed in question 17.

17. Record the following.
    a. mass of empty calorimeter (step 2)
    b. mass of calorimeter and water (step 4)
    c. mass of water alone (step 4)
    d. temperature of water in the calorimeter (step 5)
    e. temperature of water in the calorimeter immediately after ice cubes melted (step 6)
    f. mass of full calorimeter (step 7)
    g. mass of melted ice cubes (step 7)
18. Answer questions 1 to 4 of "Analyze." **Note:** For question 1, use the mass of the water in the calorimeter, not the mass of the melted ice.
19. When forming conclusions, the investigator provides an answer to "The Question" posed at the beginning of the lab.
    a. Indicate how much thermal energy is required to change the phase of 1 mol of water from solid to liquid.
    b. Identify any sources of error for the experimental value you obtained for the heat of fusion. If you had very accurate results, indicate what you think would be likely sources of error.

Check your answers with those on pages 72 and 73.

Part B

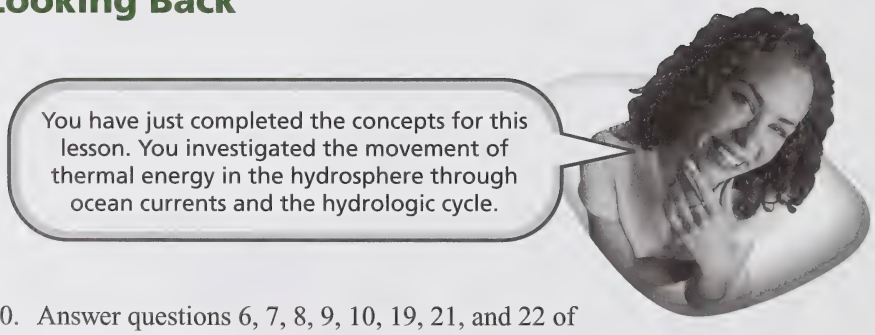
Use the following experimental data to answer questions 18 and 19 in Part A.

Mass of Empty Calorimeter (step 2)	34.5 g
Mass of Calorimeter and Water (step 4)	84.7 g
Mass of Water Alone (step 4)	50.2 g
Temperature of Water in Calorimeter (step 5)	51.5°C
Temperature of Water Immediately After Ice Cubes Melted (step 6)	28.5°C
Mass of Full Calorimeter (step 7)	98.9 g
Mass of Melted Ice Cubes (step 7)	14.2 g

As it rains, water vapour in the air undergoes a phase change that releases thermal energy. The thermal energy involved in the phase change of water has a profound effect on climate and the global transfer of energy.

Read "Phase Changes and Global Energy Transfer" on page 389 of the textbook.

Looking Back



20. Answer questions 6, 7, 8, 9, 10, 19, 21, and 22 of "Check and Reflect" on page 390 of the textbook.

Check your answers with those on pages 73 and 74.

Go to pages 7 to 11 of Assignment Booklet 4B and answer questions 20 to 27.

Glossary

calorimeter: a device used to determine the transfer of thermal energy

heat of condensation: the amount of energy released when 1 mol of a substance changes from the vapour phase to the liquid phase without a change in temperature

heat of fusion, H_{fus}: the amount of energy absorbed when 1 mol of a substance changes from the solid phase to the liquid phase without a change in temperature

heat of solidification: the amount of energy released when 1 mol of a substance changes from the liquid phase to the solid phase without a change in temperature

heat of vaporization, H_{vap}: the amount of energy absorbed when 1 mol of a substance changes from the liquid phase to the vapour phase without a change in temperature

hydrologic cycle: the process by which water molecules move from Earth's surface into the atmosphere and then back again; also called the water cycle

phase: the state of a substance (solid, liquid, or gas)

quantity of thermal energy, Q: the amount of thermal energy absorbed or released when the temperature of a specific mass of a substance changes by a certain number of degrees

$$Q = mc\Delta t$$

specific heat capacity, c: the amount of energy needed to raise the temperature of 1 g of a substance 1°C

Suggested Answers

1. The Coriolis effect, wind, and land mass change the direction of ocean currents.

2. In the northern hemisphere, ocean currents that flow north tend to be warm currents because they are coming from the warmer regions close to the equator. Ocean currents that flow south tend to be cold currents because they are coming from the cooler, polar regions.

3. Ocean currents flow clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

4. This disruption of the ocean currents is called El Niño.

5. The sample of mercury would go through the greatest temperature change because it has the smallest specific heat capacity. The sample of water would go through the smallest temperature change because it has the greatest specific heat capacity.

6. Air temperature varies more over the seasons in Lethbridge than in Vancouver because Lethbridge is inland and Vancouver is near the ocean. Most materials making up land have a low specific heat capacity in comparison to water. Therefore, they absorb or release less thermal energy than water to counter a potential temperature change.

7. **Textbook questions 1, 3, 4, 6, and 8 of "Practice Problems," pp. 379 and 380**

1. $m = 200\ \text{g}$
$c = 4.19\ \text{J/g•°C}$ (for water)
$\Delta t = 22.0°\text{C} - 4.00°\text{C}$
$= 18.0°\text{C}$
$Q = ?$

$Q = mc\Delta t$
$= (200\ \text{g})(4.19\ \text{J/g•°C})(18.0°\text{C})$
$= 1.51 \times 10^4\ \text{J}$
$= 15.1\ \text{kJ}$

The amount of thermal energy absorbed is 15.1 kJ.

3. $m = 20.0\ \text{g}$
$c = 4.19\ \text{J/g•°C}$
$\Delta t = 15.0°\text{C}$
$Q = ?$

$Q = mc\Delta t$
$= (20.0\ \text{g})(4.19\ \text{J/g•°C})(15.0°\text{C})$
$= 1.26 \times 10^3\ \text{J}$
$= 1.26\ \text{kJ}$

The amount of thermal energy that must be released is 1.26 kJ.

4. $m = 1.00\ \text{kg}$
$= 1.00 \times 10^3\ \text{g}$
$c = 2.00\ \text{J/g•°C}$
$\Delta t = 0°\text{C} - (-15.0°\text{C})$
$= 15°\text{C}$
$Q = ?$

$Q = mc\Delta t$
$= (1.00 \times 10^3\ \text{g})(2.00\ \text{J/g•°C})(15.0°\text{C})$
$= 3.00 \times 10^4\ \text{J}$
$= 30.0\ \text{kJ}$

To warm the ice, 30.0 kJ of thermal energy is required.

6. **Water**

$m = 1.00\ \text{kg}$
$= 1.00 \times 10^3\ \text{g}$
$c = 4.19\ \text{J/g•°C}$
$Q = 500\ \text{J}$
$\Delta t = ?$

$Q = mc\Delta t$

$$\Delta t = \frac{Q}{mc}$$

$$= \frac{500\ \text{J}}{(1.00 \times 10^3\ \text{g})(4.19\ \text{J/g•°C})}$$

$= 0.119°\text{C}$

Iron

$m = 1.00 \text{ kg}$
$= 1.00 \times 10^3 \text{ g}$
$c = 0.449 \text{ J/g•°C}$
$Q = 500 \text{ J}$
$\Delta t = ?$

$$Q = mc\Delta t$$
$$\Delta t = \frac{Q}{mc}$$
$$= \frac{500 \text{ J}}{(1.00 \times 10^3 \text{ g})(0.449 \text{ J/g•°C})}$$
$$= 1.11°C$$

When 500 J of thermal energy is removed from each substance, the temperature of the water drops 0.119°C and the temperature of the iron drops 1.11°C.

8. $Q = 1.95 \text{ kJ}$
$= 1.95 \times 10^3 \text{ J}$
$m = 1.00 \text{ kg}$
$= 1.00 \times 10^3 \text{ g}$
$\Delta t = 15.0°C$
$c = ?$

$$Q = mc\Delta t$$
$$c = \frac{Q}{m\Delta t}$$
$$= \frac{1.95 \times 10^3 \text{ J}}{(1.00 \times 10^3 \text{ g})(15.0°C)}$$
$$= 0.130 \text{ J/g•°C}$$

The experimental specific heat capacity of the object is 0.130 J/g•°C.

8. Data will vary. Sample data is given.

Type of Metal	iron	copper
Mass of Metal	80.0 g	90.0 g
Initial Temperature of Metal	99.1°C	98.9°C
Final Temperature of Metal	33.7°C	33.3°C
Mass of Calorimeter	1.0 g	0.9 g
Mass of Water and Calorimeter	51.0 g	51.5 g
Mass of Water in Calorimeter	50.0 g	50.6 g
Initial Temperature of Water	22.5°C	22.5°C
Final Temperature of Water	33.7°C	33.3°C

9. a. **Textbook questions 1 to 6 of "Analyzing and Interpreting," pp. 381 and 382**

1. $\Delta t = 33.7°C - 22.5°C$
$= 11.2°C$

The temperature of the water increased 11.2°C.

2. $m = 50.0\ g$
$c = 4.19\ J/g•°C$
$\Delta t = 65.4°C$
$Q = ?$

$Q = mc\Delta t$
$= (50.0\ g)(4.19\ J/g•°C)(11.2°C)$
$= 2346.4\ J$
$= 2.35\ kJ$

The water in the calorimeter absorbed 2.35 kJ of thermal energy after the iron was added.

3. $\Delta t = 99.1°C - 33.7°C$
$= 65.4°C$

The temperature of the iron decreased 65.4°C.

4. $Q = 2346.4\ J$ ← Use the unrounded value.
$m = 80.0\ g$
$\Delta t = 65.4°C$
$c = ?$

$Q = mc\Delta t$
$c = \frac{Q}{m\Delta t}$
$= \frac{2346.4\ J}{(80.0\ g)(65.4°C)}$
$= 0.448\ J/g•°C$

The experimental value for the specific heat capacity of iron is 0.448 J/g•°C.

5. i. $\Delta t = 33.3°C - 22.5°C$
$= 10.8°C$

The temperature of the water increased 10.8°C.

ii. $m = 50.6\ g$
$c = 4.19\ J/g•°C$
$\Delta t = 10.8°C$
$Q = ?$

$Q = mc\Delta t$
$= (50.6\ g)(4.19\ J/g•°C)(10.8°C)$
$= 2.289\,751\,2 \times 10^3\ J$
$= 2.29\ kJ$

The water in the calorimeter absorbed 2.29 kJ of thermal energy after the copper was added.

iii. $\Delta t = 98.9°C - 33.3°C$
$= 65.6°C$

The temperature of the copper decreased 65.6°C.

iv. Note that the thermal energy lost by the copper object equals the thermal energy absorbed by the water.

$Q = 2289.7512\ \text{J}$ ← Use the unrounded value of the thermal energy absorbed by the water.
$m = 90.0\ g$
$\Delta t = 65.6°\text{C}$
$c = ?$

$$Q = mc\Delta t$$
$$c = \frac{Q}{m\Delta t}$$
$$= \frac{2289.7512\ \text{J}}{(90.0\ \text{g})(65.6°\text{C})}$$
$$= 0.388\ \text{J/g•°C}$$

The experimental value for the specific heat capacity of copper is 0.388 J/g•°C.

6. **Iron**

$$\text{percent error} = \left|\frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}}\right| \times 100\%$$
$$= \left|\frac{0.448 - 0.449}{0.449}\right| \times 100\%$$
$$= 0.223\%$$

Copper

$$\text{percent error} = \left|\frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}}\right| \times 100\%$$
$$= \left|\frac{0.388 - 0.385}{0.385}\right| \times 100\%$$
$$= 0.779\%$$

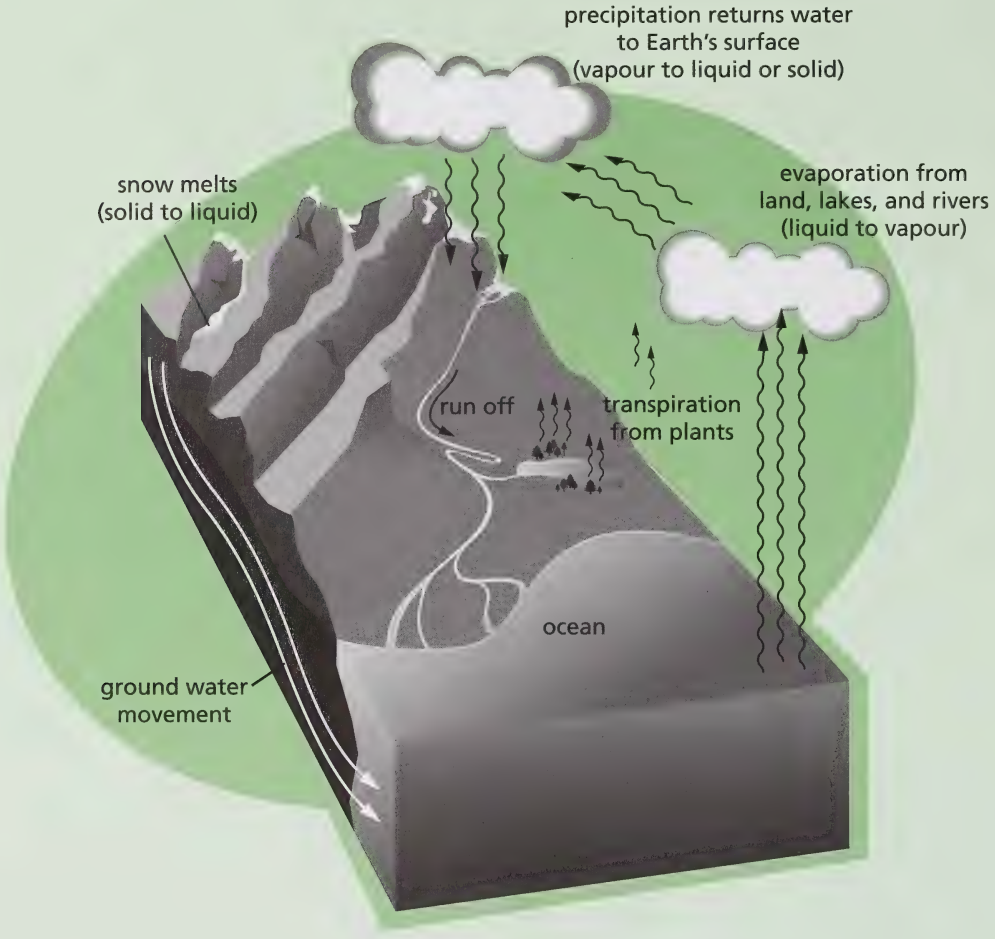
b. **Textbook questions 8 and 9 of "Forming Conclusions," p. 382**

8. The temperature change of the iron was 65.4°C. The temperature change of the water was only 11.2°C. Most of the temperature change was made by the iron, which has a much lower specific heat capacity than water. The temperature of the water is much less affected by a heat gain or loss than iron. More generally, because water has a higher specific heat capacity compared to other common substances of the lithosphere, water temperature is much more constant. The widespread existence of water and the temperature constancy of water tend to keep the rest of Earth's surface temperature constant.

9. Earth's surface is made up of substances—like water, rock, metals, and soils—with different specific heat capacities. Since the rate of heating and cooling of a substance is affected by its specific heat capacity, these substances heat up and cool down at different rates. Therefore, the differences in the specific heat capacity of substances contribute to the uneven heating and cooling of Earth's surface.

10. **Textbook questions 2 and 3 of "Check and Reflect," p. 390**

2. Water moves through the biosphere in a cyclic manner, according to the hydrologic cycle. This is shown in the following diagram.



3. The following are sources of water in the atmosphere:

   - evaporation from land and bodies of water
   - respiration by plants and animals
   - transpiration by plants

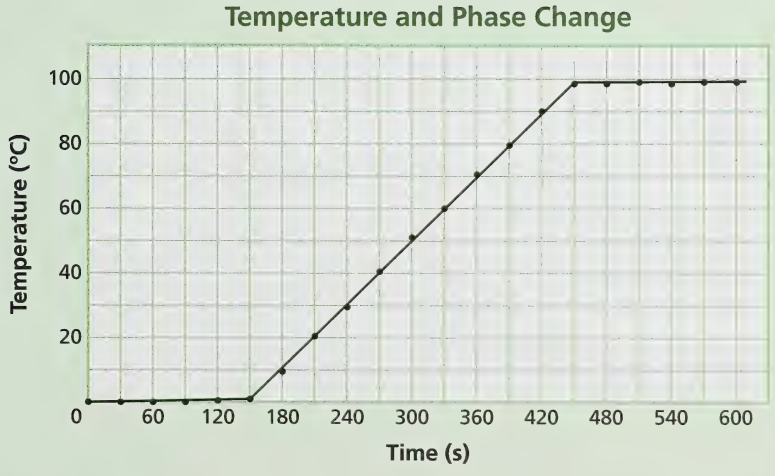
11. The temperature does not increase during a phase change because the thermal energy absorbed is used to break bonds. There is no thermal energy used to increase the kinetic energy of the water molecules. Since the kinetic energy of the molecules does not increase, the temperature of the water does not increase.

12. Although data will vary, the temperature should be constant at the beginning and end of the heating process. Sample data is given.

Time (s)	Temperature (°C)	Time (s)	Temperature (°C)
0	0.0	330	60.0
30	0.0	360	70.5
60	0.0	390	79.5
90	0.0	420	90.0
120	0.5	450	98.5
150	1.0	480	98.5
180	9.5	510	99.0
210	20.5	540	98.5
240	29.5	570	99.0
270	40.5	600	99.0
300	51.0		

13. **Textbook questions 1 to 4 of "Questions," p. 384**

    1. Graphs will vary according to the experimental data. A graph of the sample data given in the answer to question 12 is given.



2. The graph begins and ends in plateaus connected by a positively sloped line segment.

3. The plateaus represent phase changes. During phase changes, temperature is constant. All the thermal energy absorbed goes into breaking bonds rather than into increasing the kinetic energy of the molecules.

4. The manipulated variable is time, and the responding variable is temperature.

14. **Textbook question 11 of "Check and Reflect," p. 390**

11. The heat of fusion relates to the amount of thermal energy absorbed in a change from the solid phase to the liquid phase. The heat of vaporization relates to the amount of thermal energy absorbed in a change from the liquid phase to the vapour phase.

15. a. The specific heat capacity is expressed using the mass of the substance in grams.

b. The heat of fusion and heat of vaporization are expressed using the amount of the substance in moles.

16. **Textbook questions 10, 12, 14, and 15 of "Practice Problems," pp. 386 and 387**

10. $H_{fus} = 6.01$ kJ/mol
$n = 3.20$ mol
$Q = ?$

$$H_{fus} = \frac{Q}{n}$$
$$Q = nH_{fus}$$
$$= (3.20 \text{ mol})(6.01 \text{ kJ/mol})$$
$$= 19.2 \text{ kJ}$$

To completely melt the ice, 19.2 kJ of thermal energy is required.

12. $Q = 0.606$ kJ, $m = 100$ g, $M = 63.55$ g/mol, $H_{fus} = ?$

$$n = \frac{m}{M}$$
$$= \frac{100 \text{ g}}{63.55 \text{ g/mol}}$$
$$= 1.573\,564\,123 \text{ mol}$$

$$H_{fus} = \frac{Q}{n}$$
$$= \frac{0.606 \text{ kJ}}{1.573\,564\,123 \text{ mol}}$$
$$= 0.385 \text{ kJ/mol}$$

The experimental heat of fusion of copper is 0.385 kJ/mol.

Note: Another way to perform the calculation in question 12 involves combining the two formulas to form one formula. By doing this, you will avoid using rounded values from intermediate calculations.

$Q = 0.606$ kJ
$m = 100$ g
$M = 63.55$ g/mol
$H_{fus} = ?$

$$H_{fus} = \frac{Q}{n}$$
$$= \frac{Q}{\frac{m}{M}} \quad \leftarrow \text{Substitute } \tfrac{m}{M} \text{ for } n.$$
$$= \frac{QM}{m}$$
$$= \frac{(0.606 \text{ kJ})(63.55 \text{ g/mol})}{100 \text{ g}}$$
$$= 0.385 \text{ kJ/mol}$$

14. $Q = 564.0$ kJ, $m = 250$ g, $M = 18.02$ g/mol, $H_{vap} = ?$

$$n = \frac{m}{M}$$
$$= \frac{250 \text{ g}}{18.02 \text{ g/mol}}$$
$$= 13.873\,473\,92 \text{ mol}$$

$$H_{fus} = \frac{Q}{n}$$
$$= \frac{564.0 \text{ kJ}}{13.873\,473\,92 \text{ mol}}$$
$$= 40.7 \text{ kJ/mol}$$

The experimental heat of vaporization of water is 40.7 kJ/mol.

15. $m = 500$ g, $M = 18.02$ g/mol, $H_{vap} = 40.65$ kJ/mol, $Q = ?$

$$n = \frac{m}{M}$$
$$= \frac{500 \text{ g}}{18.02 \text{ g/mol}}$$
$$= 27.746\,947\,84 \text{ mol}$$

$$H_{fus} = \frac{Q}{n}$$
$$Q = nH_{fus}$$
$$= (27.746\,947\,84 \text{ mol})(40.65 \text{ kJ/mol})$$
$$= 1.13 \times 10^3 \text{ kJ}$$

To change 500 g of water from liquid phase to vapour phase, 1.13×10^3 kJ of thermal energy is required.

17. Data will vary. Sample data is given.

    a. The mass of the empty calorimeter was 34.5 g.

    b. The mass of the calorimeter and water was 84.7 g.

    c. $84.7\text{ g} - 34.5\text{ g} = 50.2\text{ g}$

    The mass of the water alone was 50.2 g.

    d. The temperature of the water in the calorimeter was 51.5°C.

    e. The temperature of the water immediately after the ice cubes melted was 28.5°C.

    f. The mass of the full calorimeter was 98.9 g.

    g. $98.9\text{ g} - 84.7\text{ g} = 14.2\text{ g}$

    The mass of the melted ice cubes was 14.2 g.

18. **Textbook questions 1 to 4 of "Analyze," p. 388**

    1. $m = 50.2\text{ g}$
       $c = 4.19\text{ J/g•°C}$
       $\Delta t = 51.5°\text{C} - 28.5°\text{C}$
       $= 23°\text{C}$
       $Q = ?$

       $Q = mc\Delta t$
       $= (50.2\text{ g})(4.19\text{ J/g•°C})(23.0°\text{C})$
       $= 4837.774\text{ J}$
       $= 4.84\text{ kJ}$

       The thermal energy transferred from the water to the ice cubes was 4.84 kJ.

    2. $m = 14.2\text{ g}$
       $M = 18.02\text{ g/mol}$
       $n = ?$

       $n = \frac{m}{M}$
       $= \frac{14.2\text{ g}}{18.02\text{ g/mol}}$
       $= 0.788\,013\,318\,5\text{ mol}$
       $= 0.788\text{ mol}$

       There were 0.788 mol of ice added.

    3. For a more accurate experimental calculation of the heat of fusion, use the unrounded values of Q and n.

       $$H_{fus} = \frac{Q}{n}$$
       $$= \frac{4.837\,774\text{ kJ}}{0.788\,013\,318\,5\text{ mol}}$$
       $$= 6.14\text{ kJ/mol}$$

       The experimental heat of fusion of ice is 6.14 kJ/mol.

4. $$\text{percent error} = \left|\frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}}\right| \times 100\%$$
$$= \left|\frac{6.14 \text{ kJ/mol} - 6.01 \text{ kJ/mol}}{6.01 \text{ kJ/mol}}\right| \times 100\%$$
$$= 2.16\%$$

The percent error of the experimental heat of fusion of ice is 2.16%.

19. a. According to the experimental results, the thermal energy required to change the phase of 1 mol of water from a solid to a liquid is 6.14 kJ/mol.

b. Sources of error could include

- loss of thermal energy through the walls of the calorimeter by conduction
- evaporation from the water surface
- accuracy of measurement

20. **Textbook questions 6, 7, 8, 9, 10, 19, 21, and 22 of "Check and Reflect," p. 390**

6. Specific heat capacity is the amount of thermal energy needed to raise the temperature of 1 g of a substance 1°C.

7. To determine the heat capacity of a substance, the following factors must be considered:

- mass of the substance, m
- temperature change, Δt
- quantity of thermal energy absorbed, Q

Hint: $Q = mc\Delta t$

8. Based on the formula $Q = mc\Delta t$, if the mass, m, and the change in temperature, Δt, is the same for two substances, the quantity of thermal energy will vary with the specific heat capacity, c. Therefore, the material with the greater specific heat capacity will absorb and contain the greater quantity of thermal energy.

Because the specific heat capacity, c, of water is greater than that of aluminium, water will contain the greater quantity of thermal energy.

9. $H_{fus} = \frac{Q}{n}$, where H_{fus} is the heat of fusion, Q is the quantity of thermal energy, and n is number of moles of the substance.

10. Heat of vaporization is the quantity of thermal energy absorbed when 1 mol of a substance changes from liquid phase to vapour phase without a change in temperature.

19. The two samples have the same mass and temperature and are made of the same material. The only difference is their phase. To change from liquid phase to vapour phase, thermal energy is absorbed. The vapour sample contains this absorbed thermal energy in addition to the quantity of thermal energy of the liquid sample. Therefore, the water vapour contains more thermal energy than liquid water. It follows that the liquid sample has less thermal energy than the vapour sample.

    Specifically, 100.0 g of liquid water at 100.0°C contains less thermal energy than 100.0 g of water vapour at 100.0°C.

21. $H_{vap} = 40.65$ kJ/mol
    $Q = 488$ kJ
    $n = ?$

$$H_{vap} = \frac{Q}{n}$$

$$n = \frac{Q}{H_{vap}}$$

$$= \frac{488 \text{ kJ}}{40.65 \text{ kJ/mol}}$$

$$= 12.0 \text{ mol}$$

    The absorption of 488 kJ of thermal energy will change 12.0 mol of water from the liquid phase to the vapour phase.

22. Water in a lake is warmed over the summer due to the increased solar energy absorbed during this season. Because of the significant mass of the water in the lake and water's high specific heat capacity, the water cools slowly when cold weather arrives. The water is still warm in the short time to the fall. But by the time spring arrives, enough time has elapsed so that the continued cooling will have left the water cold. In other words, the lake water is warmer in the fall than in the spring.

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Lesson 4

Earth's Biomes

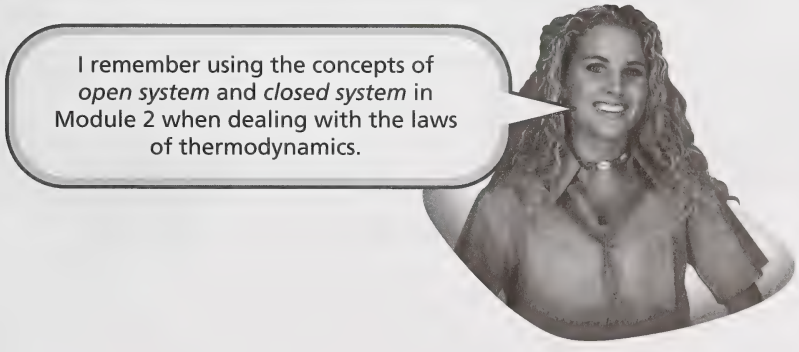
When driving from Grande Prairie, through central Alberta, and into the southeastern corner of Alberta, the natural scenery changes many times. You begin the journey in a forested area and end in a region where the natural landscape is covered by grass. On the journey you will leave one **biome** and move into another—from the taiga biome to the grassland biome.

biome: a large geographical region with a particular range of temperature and precipitation levels and the plants and animals adapted to those climate conditions

As you approach Lethbridge you may see pronghorn antelope on the dry, grassy plains. The pronghorn is not seen in regions further north in Alberta. It is adapted to conditions of the grassland biome, and its range does not extend further north.

open system: any system that exchanges both matter and energy with its surroundings

You don't have to climb a high concrete wall to move from one biome to another. There is no enclosure to prevent some matter and energy from moving into and out of biomes. Biomes function as **open systems** within the biosphere.



Turn to page 391 of the textbook and read the introduction to "Earth's Biomes" and the information in "Biomes Are Open Systems."

1. Why is a biome considered to function as a system?

2. Cells and biomes are similar in that both are open systems.

   a. Which substances move into and out of a cell during respiration?

   b. Give some examples of matter that move into and out of a biome.

   c. Chemical energy in the form of glucose coming into animal cells corresponds to the energy input of a cell. Describe the energy input and output of a biome.

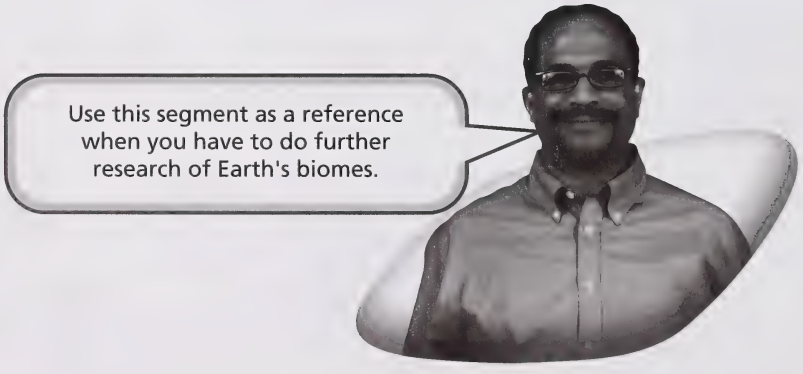
   d. The boundary of a biome is not necessarily a physical feature. Name the boundary of the cell that controls the movement of matter into and out of the cell.

Check Check your answers with those on page 79.

Alberta has two biomes. Earth's entire terrestrial biosphere is divided into six biomes:

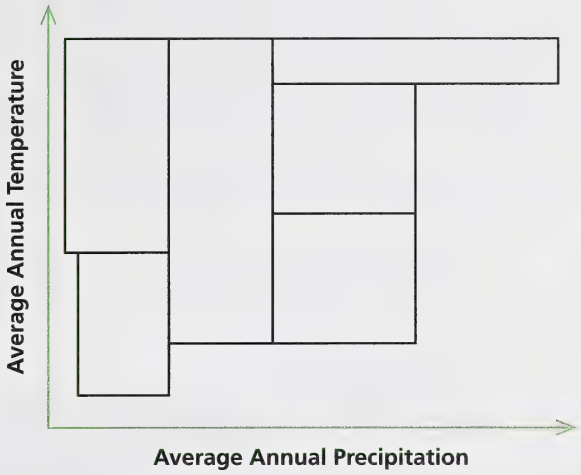
- tundra
- rain forest
- grassland
- deciduous forest
- taiga
- desert

Insert the Science 10 Multimedia CD into your computer, and view the segment "Biomes." Click the tabs that appear to see the extent of some of Earth's biomes. Also, if you click on the location for each biome, you can watch a short video and view the climate chart.



Now, turn to pages 392 to 399 of the textbook and read "Earth's Biomes."

3. Copy the following grid, and write the biome name in the section of the grid that best represents the biome. Give the graph a title.



4. The grassland biome is known as prairie in North America and savanna elsewhere. Compare the climate of a prairie to the climate of a savanna.

5. Answer questions 1, 4, 5, 6, 7, and 8 of "Check and Reflect" on page 402 of the textbook.

Check your answers with those on pages 79 and 80.

Next, you will examine more about the relation between biomes and their temperature and precipitation. You will also see which four of the six biomes exist in Canada.

Read "Biomes and Climate" and "Canada's Biomes" on pages 400 and 402 of the textbook.

6. Answer questions 10 and 11 of "Check and Reflect" on page 402 of the textbook.

Check your answers with those on page 80.

Looking Back

You have now completed the concepts for this lesson. You described the six major biomes and discovered that these biomes are distinguished by climate, vegetation, and animal population.

7. Determine the biome in which each city is located.

   a. Cairo, Egypt
   b. Churchill, Manitoba
   c. Victoria, British Columbia
   d. Lethbridge, Alberta
   e. Toronto, Ontario
   f. Manaus, Brazil

Check Check your answers with those on page 81.

Go to ... Go to pages 11 and 12 of Assignment Booklet 4B and answer questions 28 to 31.

Glossary

biome: a large geographical region with a particular range of temperature and precipitation levels and the plants and animals adapted to those climate conditions

closed system: any system that exchanges energy with its surroundings but does not exchange matter

open system: any system that exchanges both matter and energy with its surroundings

prairie: a subtype of the grassland biome found in North America

Prairies have a cooler average temperature than savannas (the other subtype of the grassland biome).

savanna: a subtype of the grassland biome found in Africa, Central America, and Australia

Savannas have distinct wet and dry seasons and a warmer average temperature than prairies (the other subtype of the grassland biome).

surroundings: everything outside of a system

system: a set of interconnected parts and an associated region containing these parts

Suggested Answers

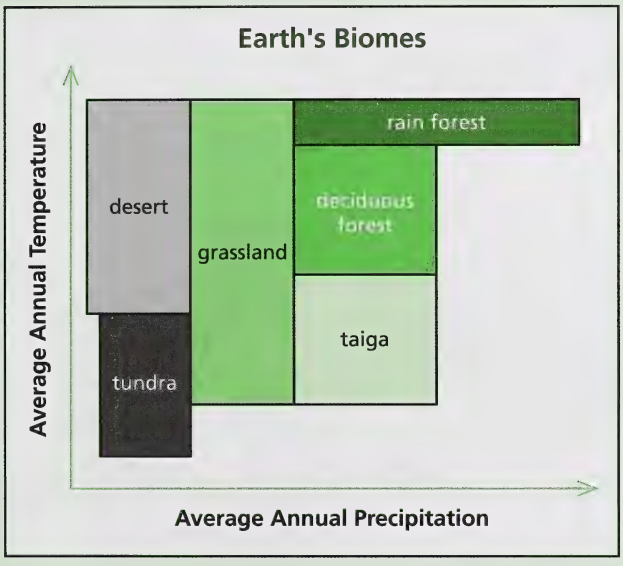
1. A biome is considered to function as a system because it consists of a set of interconnecting parts functioning together.

2. a. Nutrients and oxygen move into the cell. Carbon dioxide and other wastes move out of the cell.

   b. Some examples of matter that move into and out of a biome include migrating animals, wind, wind-blown seeds and pollen, flowing water, flying birds, and airborne pollutants.

   c. Almost all of a biome's input energy is solar energy. A biome loses energy as infrared radiation emitted into space.

   d. The boundary controlling movement of matter is the cell membrane.

3. 

4. Although the annual amount of precipitation is the same for each, the precipitation in a prairie is spread fairly evenly throughout the year. A savanna has a definite wet season and a definite dry season.

5. **Textbook questions 1, 4, 5, 6, 7, and 8 of "Check and Reflect," p. 402**

   1. A biome is a large geographic area with a particular range of temperature and precipitation levels and where the plants and animals are adapted to those climate conditions.

   4. Dividing Earth into biomes helps scientist by making it easier to

      - study the interactions between living and non-living components of a biome
      - understand how biomes interact with each other
      - predict how different groups of organisms may be affected by a drop in precipitation or any other change that may occur in a region

5. Answers will vary depending on which biome you live in. A sample answer is given.

   If you live in a prairie—a subset of the grassland biome—you likely receive precipitation ranging from 25 cm to 57 cm annually, which is spread fairly evenly throughout the year. The average annual temperature is between 4°C and 18°C, but there is a definite cold winter season and a definite hot summer season. Grasses will be the main form of natural vegetation, but there may be some drought-tolerant flowering plants, like forbs. The animals of the region include hawks, gophers, snakes, coyotes, and mice to name a few.

6. The desert and tundra biomes have very low average annual precipitation.

7. The plants and animals of Alberta's grassland biome are adapted to cold winters. The plants and animals of Sudan's grassland biome are adapted to a warmer climate having a distinct wet and dry season. In both biomes, most of the ground surface is covered by grass. The wet season of Sudan's grassland support the growth of scattered trees. Buffalo, coyotes, foxes, and rabbits are some of the animals adapted for life on the cold winters of Alberta's grassland. Animals that live in the warmer grasslands of Sudan include cheetahs, scorpions, lizards, zebras, giraffes, wildebeests, and lions.

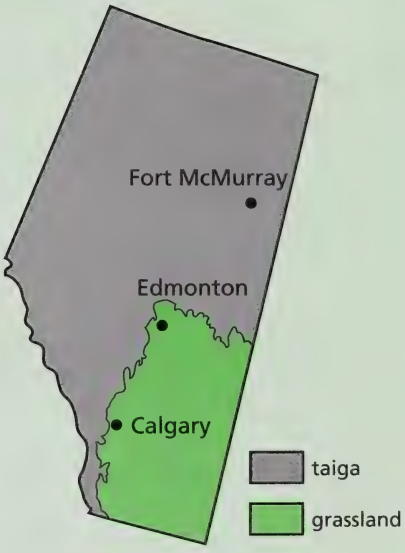
8. a. rain forest b. taiga c. deciduous forest d. desert e. tundra

6. **Textbook questions 10 and 11 of "Check and Reflect," p. 402**

10. Lists of species will vary. Sample lists are as follows.

SPECIES OF ALBERTA BIOMES

Grassland Species		Taiga Species	
Animals	Plants	Animals	Plants
pronghorn antelope	cactus	moose	spruce
gopher	sage	squirrel	pine
rattlesnake	grasses	black bear	moss



11. Answers will vary but should include a reasonable explanation. A sample answer is given.

    The grassland biome would be most affected because it is normally dry already. A general drought makes them even dryer, so there would be less moisture than the minimum necessary to sustain plant life.

7. a. desert
   b. tundra
   c. taiga
   d. grassland
   e. deciduous forest
   f. rain forest

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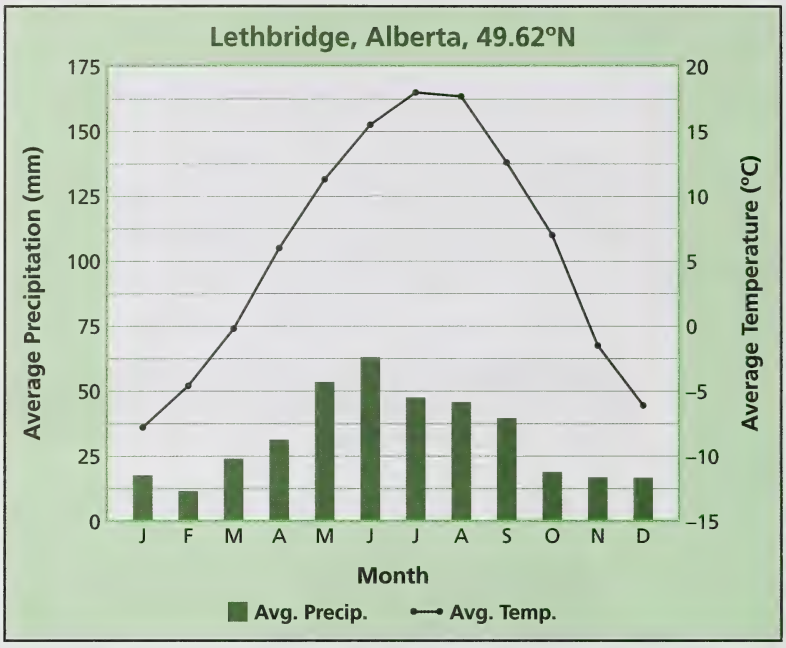
Lesson 5

Analyzing Energy Flow in Global Systems

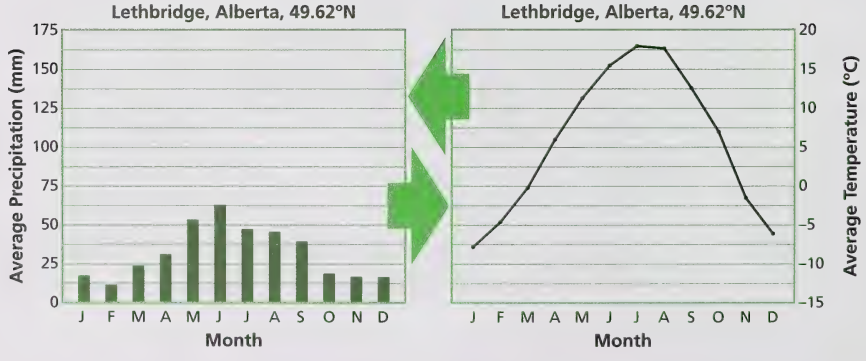
The Lethbridge Japanese Garden is a fascinating tourist attraction in southern Alberta. The garden is not a natural ecosystem; but from the flowers, pond, and bushes the horticulturists have included in the garden, a visitor might infer that the local climate is mild and somewhat humid. However, a tourist's visit to this garden may provide only a summertime impression of the climate.

climatograph: a visual summary of the average temperature and precipitation for each month of the year for a given location

A **climatograph** is a very useful way to visually summarize the climatic conditions covering an entire year. The following is the climatograph for Lethbridge, Alberta.



Note that a climatograph is really two graphs overtop one another. Both graphs just share the values of the horizontal axis. However, the bar graph corresponds to the vertical axis on the left, labelled Average Precipitation (mm), and the points along the line graph correspond to the vertical axis on the right, labelled Average Temperature (°C).



Besides conveying a concise picture of a climate, a climatograph also helps identify factors that affect the climate of a region.

Read "Analyzing Energy Flow in Global Systems " on pages 403 to 405 of the textbook. You will see how climatographs can be used to analyze climate.

1. Answer questions 1 to 4 of "Check and Reflect" on page 407 of the textbook.

Check your answers with those on pages 84 and 85.

Interpreting climate data is much easier using a climatograph than just viewing the numbers themselves. In the next activity you will make climatographs for two locations and draw conclusions based on the analysis of the climatographs.

Inquiry Lab

Using Climatographs to Compare Biomes

Read the entire activity on page 406 of the textbook.

You may wish to review graphing techniques outlined in "Student Reference 7: Graphing" on pages 472 to 477 of the textbook.

2. Construct the climatographs as outlined in the steps of the procedure. When determining ranges for temperature and precipitation, base the ranges on the data for both cities. Then use the same temperature scale and same precipitation scale for both climatographs. This will make the comparison much simpler.

3. Answer the following on page 406 of the textbook.

   a. questions 1 and 2 of "Analyzing and Interpreting"
   b. question 3 of "Forming Conclusions"

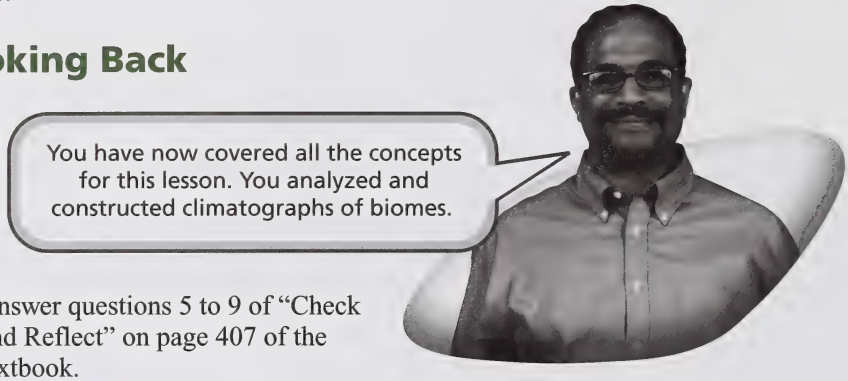
Check your answers with those on pages 85 to 87.

To review Earth's biomes and to see representative climate data graphs, go to the following NASA site:

http://eobglossary.gsfc.nasa.gov/Laboratory/Biome

Once there, click on a biome and start your mission. Keep in mind that scientists classify biomes in different ways. For example, this site refers to the shrubland biome.

Looking Back



4. Answer questions 5 to 9 of "Check and Reflect" on page 407 of the textbook.

Check your answers with those on page 88.

Go to pages 12 and 13 of Assignment Booklet 4B and answer questions 32 and 33.

Glossary

climatograph: a visual summary of the average temperature and precipitation for each month of the year for a given location

Suggested Answers

1. **Textbook questions 1 to 4 of "Check and Reflect," p. 407**

    1. Factors that play a role in determining climate are as follows:

        - insolation
        - global winds
        - type of ocean currents nearby

2. A climatograph is a summary of the average temperature and precipitation for each month of the year for a given location.

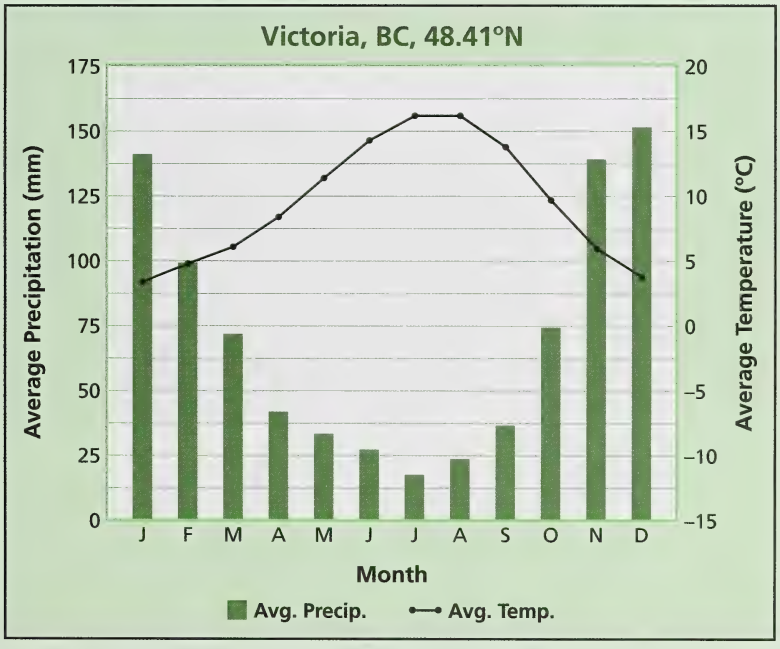
3. Precipitation and temperature are the two main two factors used in a climatograph.

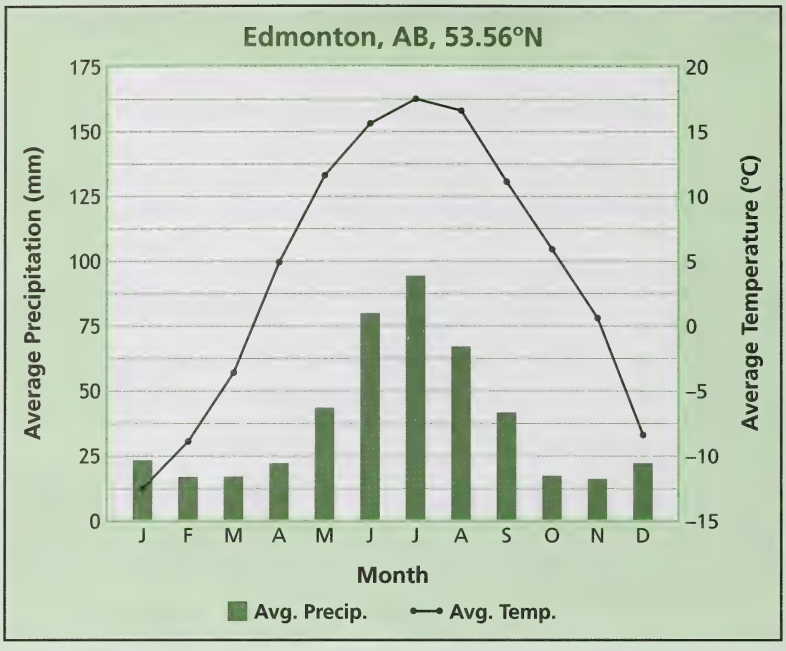
4. A coastal region has a different climate from an inland region of the same latitude because of the moderating effect of the water in the ocean.

   Water has a moderating effect because it has a high specific heat capacity compared to other common substances in the biosphere. Water absorbs and releases a large amount of thermal energy to its surrounding with only a small change in its own temperature. The thermal energy is released from water when its surroundings are cool and is absorbed when the surroundings are warm. This absorption and release of thermal energy by water opposes any tendency of the surroundings to change in temperature.

Note: Answers to questions 2 and 3 may vary according to the cities selected. The following answers are based on the data for Victoria, BC, and Edmonton, AB.

2. The climatographs for Victoria, BC, and Edmonton, AB, are as follows.





If you are having trouble creating a climatograph and are using Microsoft® Excel, follow these steps:

step 1: Build your table so "Month" is in Column A, "Average Precipitation (mm)" is in column B, and "Average Temperature (°C)" is in column C.

step 2: Select the entire table, and activate the Chart Wizard.

step 3: Click on the Custom Types tab, and select "Line-Column on 2 Axes."

step 4: Continue through the Chart Wizard to fine-tune your climatograph (inserting a title, axes labels, scale, etc.).

3. a. **Textbook questions 1 and 2 of "Analyzing and Interpreting," p. 406**

1. Victoria has a wet, mild climate with most of its precipitation falling in winter. Edmonton has a cold, moderately dry climate with most of its precipitation falling in summer. Victoria is in the taiga biome. Edmonton is in the grassland biome.

2. Victoria receives greater insolation due to its more southerly latitude. The westerlies carry thermal energy off a nearby warm ocean current, thereby moderating winter temperatures.

   Being farther north, Edmonton receives less insolation and, thus, has a lower average annual temperature. This city has no ocean (or other large body of water nearby) to moderate its temperatures. Winters are generally cold; and due to varying wind patterns, weather conditions can come from the Pacific Ocean or from the Arctic region.

b. **Textbook question 3 of "Forming Conclusions," p. 406**

3. The summer temperatures are similar in both cities, but the winter in Edmonton is much colder.

   The generally longer precipitation bars on Victoria's climatograph show that Victoria has more annual precipitation than Edmonton. Based on the pattern of precipitation bars on each climatograph, Victoria has wet winter months, whereas Edmonton has wet summer months.

   Grassland (Prairie type) at Edmonton

   climate: an average temperature of 4°C with cool summers and cold winters; annual precipitation of 461 mm

   plants: grasses, aspen poplar, prairie crocus, saskatoon, evergreens

   animals: gophers, deer, coyotes, hawks, black bears, moose, rabbits, skunks (to name just a few)

   Taiga at Victoria

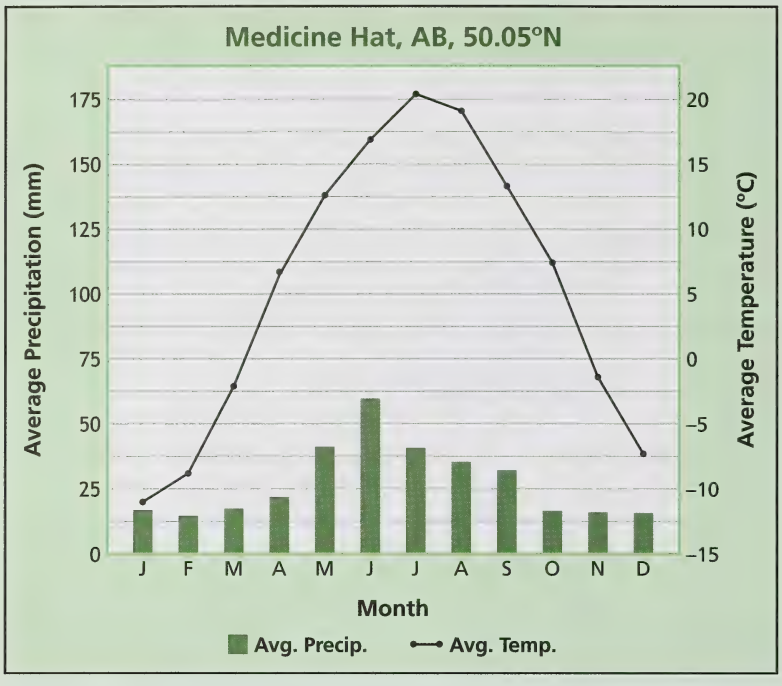
   climate: an average temperature of 10°C, with cool summers and mild winters; annual precipitation of 890 mm

   plants: evergreens, lichens, mosses, grasses

   animals: eagles, hawks, black bears, racoons, cougar, deer (to name just a few)

4. **Textbook questions 5 to 9 of "Check and Reflect," p. 407**

5.



6. Difference in altitude, proximity to water, proximity to mountains, and the effect of global wind cause differences in climate.

7. Some regions have different amounts of insolation mainly because of their latitude. Insolation varies with latitude; the greater the latitude of a region, the smaller its insolation. Also, some regions have different amounts of insolation because of differences in cloud cover and atmospheric dust.

8. The climatograph would not change significantly due to one year of colder-than-usual weather. Climatographs are based on an average taken over many years. The average of any large sample of data is not affected much by a single, atypical value.

9. Precipitation is highest in the months of the year when temperature is highest; it is lowest in the months when temperature is lowest.

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Conclusion

In this section you identified the Sun as the source of all energy flowing through the biosphere. You investigated factors that affect the amount of solar energy reaching Earth's surface. You found that variation in the absorption of solar energy around the globe leads to a global energy transfer. This energy transfer is responsible for the various climatic conditions on Earth. You later related climatic conditions to Earth's biomes.

The flow of thermal energy absorbed from the Sun is essential in maintaining a variety of climate zones and biomes.

The large taiga biome circles Earth in the northern hemisphere and includes much of the province of Alberta. It is the mixture of precipitation, direct solar energy, and thermal energy transfer that maintains the conditions that support the moose and its community of plants and animals.

Human Activity and Climate Change

Polar bears stalk seal—their main source of food—from ice platforms. They wait at cracks in the ice where seals come up for air to snatch their prey. Once the spring breakup arrives, polar bears can no longer continue their hunt. During the summer, polar bears fast and live off stored fat. They can only return to their seal hunt once the ice platforms form again in the autumn.

Today, the polar bear is threatened by a climate change. Compared to 20 years ago, the ice break comes earlier and the ice platforms form later in the autumn. This increases the time during which the water is open and during which polar bears must live on stored fat. The result is that the polar bears on shore are in poorer condition and their population has fallen. The plight of the polar bear is serious, but imagine the impact of ongoing climate change. It will be much more widespread.

In this section you will identify and evaluate evidence that shows climate change is happening now. You will identify human activities that may be contributing to climate change and assess the impact of climate change on human society and on life in the biosphere. You will also describe plans to curb the effects of human activities on climate change.

Turn to page 410 of the textbook and read the introduction to Unit D 3.0. Pay particular attention to the key concepts and learning outcomes listed. They provide a brief overview of what you will cover in this section.

Lesson 1

Climate Change—Examining the Evidence

Isaac's favourite activity is snowboarding. Each year, he can't hardly wait for the day the ski slope opens for the season. The operators of the ski hill must wait until enough snow has accumulated before they can open the hill. Isaac knows that the snowfall and temperature vary before every ski season. Such fluctuations in weather conditions always affect the start of every ski season.

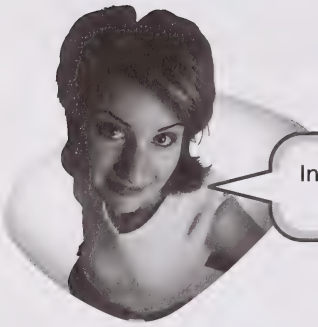
The fact that weather conditions change is clear from daily experiences. But you may be surprised to learn that climate itself may be changing too. Some of this evidence comes from fossil records. Additional evidence that has allowed scientists to study climate comes from the distribution of pollen sample in layers of lake sediment and from the growth rings of trees.

Going Further

To find out more about using tree rings to investigate climate of the past, visit the following website:

http://www.scienceman.com/science10

Once there, click on "Unit D: Hot Links" and scroll down to Text Page 341. You will be provided with a list of informative sites.



In the next activity, you will interpret patterns in growth rings from several samples

Quicklab

Climate and Tree Growth

Read the entire activity on page 341 of the textbook.

1. Complete the table as described in the steps outlined in the procedure.
2. Answer question 1 of "Questions."

Check your answers with those on page 96.

During the twentieth century, Earth's average surface temperature increased by 0.6°C. That may not seem alarming to you, but this increase is very atypical. It has never occurred in the previous 10 000 years over any 100-year span. Is there something upsetting the natural greenhouse effect?

Turn to pages 411 and 412 of the textbook and read the introduction to "Climate Change—Examining the Evidence" and the information in "Changes in Greenhouse Gases."

3. Answer questions 1, 2, and 3 of "Check and Reflect" on page 418 of the textbook.

Check your answers with those on pages 96 and 97.

extrapolation: a process of estimating the value of a measurement beyond the known values of a set of data

Through **extrapolation**, scientists can predict future scenarios. Make some predictions of your own based on the graphs of greenhouse gas concentrations.

Read "Skill Practice: Extrapolating Data" on page 412 of the textbook.

4. Answer questions 1 to 6 of "Skill Practice: Extrapolating Data."

Check your answers with those on pages 97 to 99.

Scientists compare the trend in the concentration of greenhouse gases and the trend in global temperature. Is there a causal relation between greenhouse-gas concentration and global temperature? Have human activities played a role in the rise of global temperatures? Think about these questions as you do the next reading.

Turn to pages 413 to 415 of the textbook and read "Greenhouse Gases and Human Activity."

5. Humans have introduced one group of greenhouse gases into the atmosphere. These gases do not occur in the atmosphere naturally. What is the name of this group of artificial greenhouse gases?

6. Answer questions 8, 10, and 11 of "Check and Reflect" on page 418 of the textbook.

Check your answers with those on page 99.

Going Further

Imagine deliberately producing greenhouse gases for release into the atmosphere. This has been considered for Mars. Find out why this might serve a useful purpose by reading "Using Global Warming to Create Conditions for Life on Mars" at the following Internet site:

http://www.marstoday.com/viewpr.html?pid=16055

Scientists' knowledge of the factors affecting global climate is vast but still incomplete. Consequently, there are different views as to how Earth's biosphere will be affected in the long term by climate change. As well, some scientists differ in the predictions they make from the available climate data.

Read "Evaluating the Evidence of Climate Change " and "Other Views on Climate Change" on pages 415 to 418 of the textbook.

Going Further

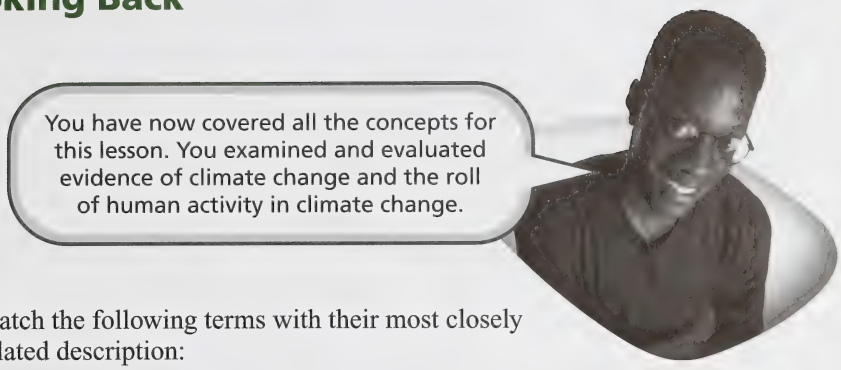
In the reading, you found that not everyone agrees about the cause of global warming and its consequence. Use the Internet to find widespread views on global warming.

For contrary views, begin searching the Internet by entering the terms *deny global warming*. Of course, the validity of the sites you find may be questionable and may not be based on the work of climatologists. To evaluate information provided on the Internet, consider the author and any bias that may be affecting the content.

7. Answer question 13 of "Check and Reflect" on page 418 of the textbook.

Check your answer with the one on page 99.

Looking Back



8. Match the following terms with their most closely related description:

i. carbon sink	ii. carbon source
iii. fossil fuel	iv. halocarbons
v. enhanced greenhouse effect	

a. carbon-based fuels
b. composed of carbon and halogens
c. makes Earth's average temperature rise
d. puts carbon dioxide into the atmosphere
e. takes carbon dioxide out of the atmosphere

Check Check your answers with those on page 99.

Go to ... Go to pages 1 to 4 of Assignment Booklet 4C and answer questions 1 to 11.

Glossary

carbon sink: any process that removes carbon dioxide from the atmosphere

e.g., photosynthesis

carbon source: any process that releases carbon dioxide into the atmosphere

e.g., burning of fossil fuels

enhanced greenhouse effect: the observed increase in Earth's average temperature

extrapolation: a process of estimating the value of a measurement beyond the known values of a set of data

fossil fuel: a carbon-based fuel formed from the remains of living organisms

e.g., coal, oil, and natural gas

halocarbon: any of various compounds of carbon and one or more halogens

Halocarbons are human-made chemicals, such as chlorofluorocarbons (CFCs), that absorb large quantitities of thermal energy.

IPCC: Intergovernmental Panel on Climate Change; an international group of scientists who assess information related to climate change

Suggested Answers

1. Answers may vary slightly. A sample answer is given.

Sample	Age (years)	Wet and Cool	Dry and Hot
1	30	1981–1983 1992–1994 1998–2002	1973–1980 1984–1991 1995–1997
2	27	1981–1983 1992–1994 1998–1999	1973–1980 1984–1991 1995–1997
3	38	1964 1966 1971–1972 1981–1983 1992–1994	1960–1963 1965 1967–1970 1973–1980 1984–1991 1995–1997
4	27	1956–1958 1964 1966 1971–1972	1953–1955 1959–1963 1965 1967–1970 1973–1979

2. **Textbook question 1 of "Questions," p. 341**

    1. Core samples of trees indicate the growth rings of trees. The spacings of the growth rings indicate the humidity and temperature of each year of the life of the tree. Note that the spacing may be affected by, among other factors, the length of the growing season and population of insect pests feeding on the tree.

3. **Textbook questions 1, 2, and 3 of "Check and Reflect," p. 418**

    1. Global Warming Potential (GWP) is the measure of the ability of a gas in the atmosphere to trap thermal energy. GWP of a gas is indicated relative to the GWP of carbon dioxide, which is given a GWP of 1.

2. Carbon dioxide, nitrous oxide, and methane are greenhouse gases generated by human activity. The atmospheric concentrations of these greenhouse gases have increased over the last 200 years with most of the increase occurring in the last 100 years. **Note:** Halocarbons will be described as greenhouse gases in the next reading from the textbook.

3. Scientists use ice core samples and direct atmospheric measurements to measure greenhouse-gas concentrations over time.

4. **Textbook questions 1 to 6 of "Skill Practice: Extrapolating Data," p. 412**

1. All three gases have increased in concentration (exponentially).

2. The following table shows the increase of each gas.

Gas	Concentration (ppm)		Total Increase (ppm)
	1750	2000	
CO_2	280	365	85
N_2O	0.275	0.310	0.035
CH_4	0.750	1.750	1.000

3. percent increase of $CO_2 = \frac{\text{final value} - \text{initial value}}{\text{initial value}} \times 100\%$

$= \frac{365 \text{ ppm} - 280 \text{ pmm}}{280 \text{ ppm}} \times 100\%$

$= 30.4\%$

percent increase of $N_2O = \frac{\text{final value} - \text{initial value}}{\text{initial value}} \times 100\%$

$= \frac{0.310 \text{ ppm} - 0.275 \text{ pmm}}{.275 \text{ ppm}} \times 100\%$

$= 12.7\%$

percent increase of $CH_4 = \frac{\text{final value} - \text{initial value}}{\text{initial value}} \times 100\%$

$= \frac{1.750 \text{ ppm} - 0.750 \text{ pmm}}{0.750 \text{ ppm}} \times 100\%$

$= 133\%$

Note: A spreadsheet can be used for the calculations you performed in questions 2 and 3.

	A	B	C	D	E
1		Concentration (ppm)		Total	Percent
2	Gas	1750	2000	Increase (ppm)	Increase (%)
3	CO_2	280	365	85	30.4
4	N_2O	0.275	0.310	0.035	12.7
5	CH_4	0.750	1.750	1.000	133.3

	A	B	C	D	E
1		Concentration (ppm)		Total	Percent
2	Gas	1750	2000	Increase (ppm)	Increase (%)
3	CO_2	280	365	=C3-B3	=D3/B3*100
4	N_2O	0.275	0.310	=C4-B4	=D4/B4*100
5	CH_4	0.750	1.750	=C5-B5	=D5/B5*100

4. Answers will vary. It depends on how you choose to extrapolate the data. The following extrapolation is based on a linear projection rather than an exponential projection, which would yield even higher values.

   Over the next 100 years, the percent increase would be $\frac{100}{250}\times$ the percent increase calculated in question 3.

   Consider the year 2000 as the present. Then the increase in concentration of each gas is equal to the present concentration multiplied by the percent increase. This increase is then added to the present concentration to give the future concentration (after 100 years).

Gas	Concentration (ppm)		Total Increase (ppm)	Percent Increase (%)	Projected Increase in 100 Years	
	1750	2000			Percent (%)	Amount (ppm)
CO_2	280	365	85	30.4	12.1	409
N_2O	0.275	0.310	0.035	12.7	5.1	0.326
CH_4	0.750	1.750	1.000	133.3	53.3	2.683

5. Answers may vary. It is important to be aware of assumptions made when making projections.

   The major assumption in the answer to question 4 is that the emission of these greenhouse gases will continue at a constant rate, based on the average rate found over the last 250 years. **Note:** It is reasonable to base the average rate of emissions on the period 1950 to the present or some other shorter period other than 250 years. That will affect the projected values of greenhouse-gas concentrations.

6. Answers will vary. You should be more confident about the answer to question 2. This answer was based on actual data. The answer to question 4 was based on extrapolation, which was based on assumptions. The accuracy and certainty of values resting on assumptions and projected through extrapolation are lower than directly measured values.

5. The group of artificial greenhouse gases is called halocarbons.

6. **Textbook questions 8, 10, and 11 of "Check and Reflect," p. 418**

   8. Imagine sending one of your lab reports to someone who is also taking Science 10. Another person having your level of expertise in science would likely catch errors (if any) in your data or conclusions. You would likely be more confident in your work if you collaborated in this way.

      The IPCC uses a similar method—peer review—to improve the confidence in scientific work they assess. By sending out work to other scientists for evaluation, the IPCC can be highly confident that errors, omissions, and invalid conclusions are avoided in work that is approved.

   10. After the Industrial Revolution, the following occurred on a large scale:

       - the burning of fossil fuels
       - deforestation
       - emissions of methane and nitrous oxide from agriculture
       - industrial emissions of halocarbons, such as CFCs

   11. Through photosynthesis, plants function as a carbon sink. During photosynthesis, plants use carbon dioxide and convert it into food. In this way, plants remove an important greenhouse gas from the atmosphere.

7. **Textbook question 13 of "Check and Reflect," p. 418**

   13. Answers may vary. You should understand that when evaluating science, "wrong" and "right" are at the ends of a continuum. Dealing with scientific work is not a black-and-white issue. Science does not deal solely with factual observation. It involves making conclusions from limited data that may be interpreted in more than one way. As new data becomes available and understanding improves, interpretations change and conclusions are modified.

8. a. iii b. iv c. v d. ii e. i

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Lesson 2

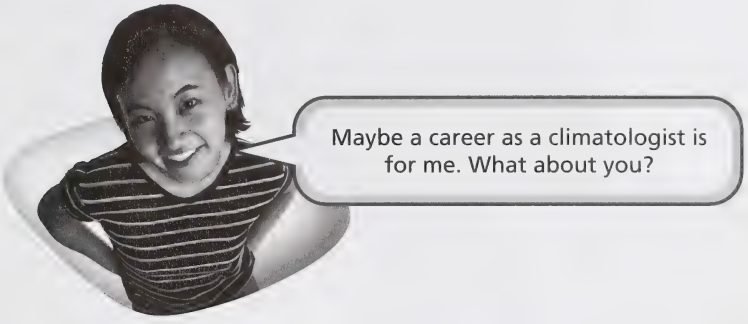
International Collaboration on Climate Change

Dacey and Chen were playing with the globe in their classroom. Together, they found that they could easily identify about 45 countries without looking at their names. But there were so many countries they were not familiar with. So, Dacey and Chen began counting how many countries there were in the world. After losing count after 100, they figured it would be much easier to look it up on the Internet. To their surprise, Dacey and Chen found there were 193 countries recognized by the United Nations.

Human activities in many of the world's countries are contributing to the recent rise in global temperature. The effects of these human activities spill over the borders of individual countries and even continents. To counter global warming, collaboration is needed on a global scale. Scientists and political leaders need to collaborate on global warming. No one country can deal with this issue alone.

Turn to page 419 of the textbook and read the introductory paragraph of "International Collaboration on Climate Change" and the information in "Scientific Collaboration on Climate Change."

Now that you have a better idea of scientific collaboration on climate change, read an interview with Andrew Weaver, an expert on climate change. Turn to page 420 of the textbook and read "Career and Profile."



1. Answer question 2 of "Check and Reflect" on page 425 of the textbook.

2. Name a type of computer climate model that focuses on the changes affecting Earth's energy balance and on the global thermal energy transfer in the atmosphere.

3. International collaboration in science is based on the technology and research expertise of individual countries, like Canada.

   a. Which Canadian climate researcher developed the UVic Earth System Climate Model?

   b. How will the UVic Earth System Climate Model help climatologists?

   c. How is the UVic Earth System Climate Model tested?

4. Name an important source of scientific information that informs government policy decisions in countries around the world.

5. Name some new technological tools used to obtain data from parts of Earth that were formerly inaccessible.

6. Refer to Figure D3.15 on page 421 of the textbook. It shows the thickness of the ozone layer over Antarctica. Indicate what technological tool was used to make this image.

Check your answers with those on pages 104 and 105.

United Nations Building in New York City

Although climatologists are continuing their research into global energy systems, there is already enough indication that human activity has an effect on global climate. With this in mind, what should be done to counter these effects on the climate? This is a question that must be answered through political decision making and collaboration.

Read "Political Collaboration on Climate Change" on pages 421 and 422 of the textbook.

7. Match each description with a term from the following list.

i. HCFCs	ii. Kyoto Protocol
iii. Montreal Protocol	iv. ozone
v. sustainable development	vi. UNFCCC

   a. agreement to phase out chlorofluorocarbons

   b. more environmentally friendly replacement for chlorofluorocarbons

   c. sets out the general process for making international action-plan agreements relating to climate change

   d. the use of natural resources with minimal impact on supply to future generations

   e. an international agreement to stabilize the production of greenhouse gases

   f. an atmospheric gas that shields life from harmful ultraviolet radiation from the Sun

8. According to the Kyoto Protocol, Canada must reduce its greenhouse gas emissions to _____.

9. Answer questions 4, 5, and 7 of "Check and Reflect" on page 425 of the textbook.

Check

Check your answers with those on page 105.

In the face of costs associated with compliance, the Kyoto Protocol represents a political will to control greenhouse gas emissions. Scientists have developed ideas, such as **carbon dioxide sequestering**, to help meet commitments to the Protocol. Industries and individuals are also making strides toward global, climate-friendly choices.

carbon dioxide sequestering: a process of pumping carbon dioxide gas into the ground and storing it in sealed containers

Read "Economics and the Kyoto Protocol " and "Stabilizing Greenhouse Gas Levels" on pages 423 to 425 of the textbook.

10. Answer questions 9, 11, 12, and 13 of "Check and Reflect" on page 425 of the textbook.

Check Check your answers with those on pages 105 and 106.

Looking Back

You have just completed the concepts for this lesson. You described the role of science, technology, and international collaboration in studying climate change and responding to its potential impact.

11. Answer questions 8 and 10 of "Check and Reflect" on page 425 of the textbook.

Check Check your answers with those on page 106.

Go to ... Go to pages 4 to 6 of Assignment Booklet 4C and answer questions 12 to 17.

Glossary

anthropogenic: resulting from the influence of humans

carbon dioxide sequestering: a process of pumping carbon dioxide gas into the ground and storing it in sealed containers

emission-reduction credits (ERCs): credits given to a country under the Kyoto Protocol for actions that contribute to the global reduction of greenhouse gas emissions

general circulation model (GCM): a climate model that incorporates the laws of physics to model climate on a global scale

hydrochlorofluorocarbon (HCFC): a compound that has similar properties to CFCs but destroys ozone much more slowly

Kyoto Protocol: an international agreement to reduce the emission of greenhouse gases

Montreal Protocol: an international agreement to phase out the production and use of CFCs

sustainable development: the use of the world's resources in a way that keeps the resources for future generations

UNFCCC: United Nations Framework Convention on Climate Change; an agreement by the world's nations to act in ways that will stabilize greenhouse gas emissions from anthropogenic sources

Suggested Answers

1. **Textbook question 2 of "Check and Reflect," p. 425**

   2. Climate change affects the whole biosphere and all the countries in the international community. Research should be based on climate data from all countries and the expertise of the international scientific community.

2. The general circulation model (GCM) focuses on the changes affecting Earth's energy balance on the global thermal energy transfer in the atmosphere.

3. a. Dr. Andrew Weaver (and his team) developed the UVic Earth System Climate Model.

   b. The UVic Earth System Climate Model will help climatologists understand the feedback between land and ocean surface properties and climate conditions that occurred over the last 400 000 years.

   c. The UVic Earth System Climate Model is tested by comparing modelling results with some actual climate data (collected by other means).

4. IPCC reports are an important source of scientific information that influences government policy decisions.

5. Satellites, high-altitude jets, and deep-sea submarines are now used to obtain data from parts of Earth that were formerly inaccessible.

6. This image was made using computer simulation.

7. a. iii b. i c. vi d. v e. ii f. iv

8. According to the Kyoto Protocol, Canada must reduce its greenhouse gas emissions to **6% below 1990 levels**.

9. **Textbook questions 4, 5, and 7 of "Check and Reflect," p. 425**

    4. CFCs—chlorofluorocarbons—are a type of halocarbon. Halocarbons are stable, artificial substances that were used as propellants in aerosol cans and fire extinguishers. They were also used as coolants in refrigerators and air conditioners.

    5. By setting out a general process, the United Nations Framework Convention on Climate Change (UNFCCC) paved the way for future agreements related to climate change. It was also the first formal acknowledgment by the international community that climate change was related to the effects of human activity.

    7. Emission-reduction credits (ERCs) are credits given to a country that contributes to the global reduction of greenhouse gas emissions. Canada can earn these credits by helping a developed country reduce its emissions or by planting trees (a practice to help remove carbon dioxide from the atmosphere).

10. **Textbook questions 9, 11, 12, and 13 of "Check and Reflect," p. 425**

    9. Carbon dioxide sequestering is any process that removes carbon dioxide from the atmosphere through storage. This process may involve pumping carbon dioxide into the ground to keep it out of the atmosphere. Sometimes carbon dioxide is sequestered in conjunction with its use in extracting oil from underground reserves.

    11. Simpler computer climate models are used for some climate research because such models may run on available computers rather than requiring expensive supercomputer time. Yet, the simpler computers may be adequate for a limited analysis involving only a few independent variables.

    12. Answers will vary. Industries in Canada could reduce greenhouse gas emissions by

        - using wood normally wasted rather than fossil fuel for thermal energy
        - using cogeneration for thermal energy
        - using teleconferencing rather than face-to-face meetings when long distances are involved

13. Answers will vary. The problems in implementing the Kyoto Protocol stem from the unwillingness of some countries to ratify the treaty. This unwillingness is based on a concern that implementing the treaty would be

    - too costly with costs borne unevenly among signatories
    - result in unemployment and inflation
    - stifle basic economic development in some developing countries

    Note: In general, developing countries are not required to meet emission-reduction targets to allow for future economic growth. However, China, India, and Latin America will be required to make reductions in CO_2 emissions starting in 2012.

11. **Textbook questions 8 and 10 of "Check and Reflect," p. 425**

    8. Answers will vary. A sample answer is given.

       Riding a bike, taking public transit, turning down the thermostat, and walking instead of driving a car are choices that reduce greenhouse gas emissions.

    10. There would have to be the political will among countries of the world to take action in spite of the potential economic costs in the short term.

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Lesson 3

Assessing the Impacts of Climate Change

If you spent the summer of 2003 in Kelowna, BC, you would not easily forget the forest fires that threatened residents. The unusually hot, dry summer provided fertile conditions for the ferocious forest fires that destroyed 200 homes and forced 30 000 residents to flee their homes. Almost 850 fires were ablaze over an area of 135 000 hectares.

Maybe the hot, dry summer of 2003 was a naturally occurring one. On the other hand, maybe the drought was an example of a severe weather event associated with global climate change. Thinking of the destructive aftermath of this unusual summer leads to the query, "What future events can you expect from global climate change?"

It is time for you to apply your prior knowledge by checking the validity of the statements in question 1 concerning the impacts of climate change. Try to answer the question based on what you already know or think you know. However, you may want to review your notes and check Internet sources again as you make a decision about each statement.

The following websites will provide information to help you with your decision regarding the impact statements:

- *Taking Action on Climate Change*

  http://www.climatechange.gc.ca

- *Sila: Clue in to Climate Change*

  http://www.nature.ca/sila

- *Climate Change Impacts in North America*

  http://www.climate.org/topics/climate/impacts_na.shtml

1. For each statement, answer "Yes" for those statements you agree with and "No" for those you disagree with. For those you do not agree with, rewrite a corrected version of the statements.

   a. Climate change will lead to more tornadoes and thunderstorms.

   b. Droughts will become rare and less severe.

   c. The habitat of Arctic species will shrink.

   d. As permafrost thaws, more greenhouse gases will be released.

   e. In Alberta, agriculture workers might have to replace winter wheat with canola crops due to changing climatic conditions.

   f. In northern parts of Canada, agriculture could possibly benefit from climate change.

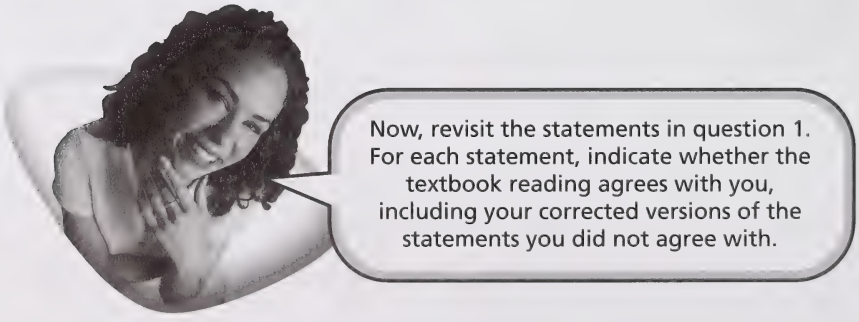
   g. The population of insects harmful to Alberta forests would decrease due to climate change.

   h. With rapid climate change, animals depending on wetlands would be at increased risk of extinction.

   i. Significantly warmer climate conditions would introduce Lyme disease into Alberta.

Check your answers with those on page 111.

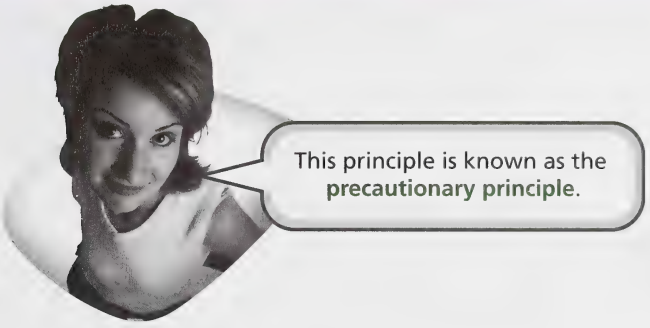
Turn to page 426 of the textbook and read the introduction to "Assessing the Impacts of Climate Change." Examine Figure D3.22 closely. Then read "Impacts of Climate Change on Alberta" on page 427.



The United Nations Conference on Environment and Development met in Rio de Janeiro, Brazil, in 1992. From this conference came the following principle.

". . . Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[1]

precautionary principle: a principle stating that the lack of full scientific certainty will not be used as a reason to postpone measures to prevent environmental damage



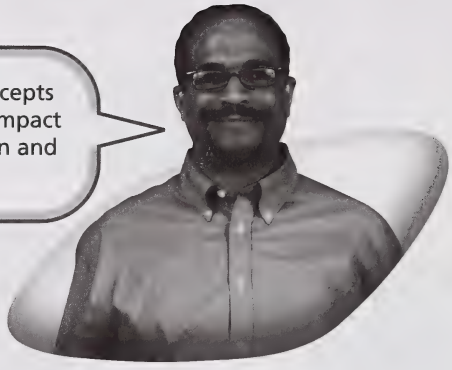
Turn to pages 429 and 430 of the textbook and read "Canada's Action Plan on Climate Change" and "Balancing Environmental, Social, and Economic Goals." You will learn about Canada's action plans that deal with threats of serious and irreversible damage as a result of climate change.

2. Answer questions 1, 4, 6, 8, 10, and 12 of "Check and Reflect" on page 430 of the textbook.

Check your answers with those on pages 111 and 112.

[1] Excerpt from Principle 15 of the RIO DECLARATION ON ENVIRONMENT AND DEVELOPMENT. (June 1992) http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm 10 August, 2005.

Looking Back



3. Match each sector with the associated action from *The Government of Canada's Action Plan 2000 on Climate Change* on page 429 of the textbook.

   i. Energy
   ii. Buildings
   iii. Industry
   iv. Transportation
   v. Agriculture and Forestry

   a. builds storage sites for carbon dioxide

   b. conducts audits of energy-efficiency

   c. develops technologies, such as hydrogen-powered fuel cells

   d. encourages businesses to install energy-efficient heating and cooling systems

   e. promotes the planting of trees

Check Check your answers with those on page 112.

Go to ... Go to pages 6 and 7 of Assignment Booklet 4C and answer questions 18 to 22.

Glossary

precautionary principle: a principle stating that the lack of full scientific certainty will not be used as a reason to postpone measures to prevent environmental damage

Suggested Answers

1. **Note:** The bolded text in the statements that have been rewritten represent the changes made.

   a. Yes

   b. No. Droughts **could** become **more** common and **more** severe.

   c. Yes

   d. Yes

   e. No. In Alberta, agriculture workers might have to replace **canola** with **winter wheat** crops due to changing climatic conditions.

   f. Yes

   g. No. The population of insects harmful to Alberta forests **could increase** due to climate change.

   h. Yes

   i. Yes

2. **Textbook questions 1, 4, 6, 8, 10, and 12 of "Check and Reflect," p. 430**

   1. Answers may vary. Consequences include more extreme weather events, the shifting of the taiga/grasslands boundary northward, and drier weather.

   4. Answers will vary. Some potential consequences to agriculture are longer growing seasons, more droughts, and more pests; but, generally, there will be an increase in crop yields.

   6. The Government of Canada has targeted the Transportation, Energy, Buildings, Agriculture and Forestry, and Industry sectors for its focus on reduction in greenhouse gas emissions.

8. The Agriculture and Forestry sector could benefit from climate change because of a longer growing season. This would allow for a greater production of crops and a wider variety in crops and trees to grow.

10. Answers will vary. Some positive changes that could be made in day-to-day business would be cycling or taking public transportation to work or school, planting trees, and using energy-efficient products.

12. Climate change could reduce the amount of snow and the length of the winter season. Then there would be fewer tourists coming to Alberta to ski in the mountains. Hot summer weather could also discourage tourists from coming.

3. a. i b. iii c. iv d. ii e. v

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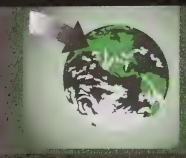
Conclusion

In this section you studied evidence that indicates past trends in climatic conditions and that climate change is happening. You identified human activities that may be contributing to climate change and assessed the impact of climate change on human society and on Earth's biomes. You also described strategies to reduce the effects of human activities on climate change.

With international collaboration in studying climate change and agreements to reduce the effects of human activities on climate, dire predictions based on climate change may be avoided.

The impact of climate change is global; however, the threat of climate change on the remaining 23 000 polar bears roaming the Arctic can serve as a warning. The Kyoto Protocol may be critical in stabilizing climate conditions. This international agreement may ensure that ice platforms on Arctic waters will be there in the future to support the polar bear.



Module Summary

In this module you investigated the importance of solar energy in maintaining global climatic conditions necessary for life to exist on Earth. With an understanding that climates have changed in the past, you evaluated evidence that human activities may be causing climates to change too rapidly.

In Section 1 you described the atmosphere, hydrosphere, and lithosphere as components of the biosphere. You also explained how climate keeps the biosphere suitable for life and examined evidence that the global climate may be changing.

In Section 2 you identified the Sun as the source of all energy flowing through the biosphere. You investigated factors that affect the amount of solar energy reaching Earth's surface. You then found that variations in the absorption of solar energy around the globe leads to a global energy transfer. This energy transfer is responsible for the various climatic conditions. You later related climatic conditions to Earth's biomes.

In Section 3 you studied evidence indicating past trends in climatic conditions and that climate change is currently happening. You identified human activities that may be contributing to climate change and assessed the impact of climate change on human society and on Earth's biomes. You also described strategies to reduce the effects of human activities on climate change.

In a conservatory or greenhouse, thermostats and other control devices maintain conditions suitable for living things. Conditions in the natural world are a product of the global climate. The global climate may be affected in unpredictable ways by large-scale human activities.

From space, Earth is a remarkable oasis in a backdrop of darkness. It is important that humans agree to protect the global climate—life on Earth depends on it.

Module Review

You have now covered all of the concepts for this module. To review what you covered, answer the following "Unit Review" questions on pages 435 to 438 of the textbook. If necessary, go back and read over the parts of this module as you answer the questions.

1. questions 2, 4, 6, 7, 9, 10, 12, 16, 18, 20, 21, 22, 24, 26, 29, 33, 38, 42, 48, 52, 54, 57, 60, 61, and 62 of "Knowledge"

2. questions 64, 68, 85, 89, 93, and 96 of "Applications"

3. questions 97, 99, and 104 of "Extensions"

4. question 107 of "Skill Practice"

Check your answers with those on pages 116 to 119.

Suggested Answers

1. **Textbook questions 2, 4, 6, 7, 9, 10, 12, 16, 18, 20, 21, 22, 24, 26, 29, 33, 38, 42, 48, 52, 54, 57, 60, 61, and 62 of "Knowledge," pp. 435 and 436**

2. Weather is the daily state of the atmosphere, such as temperature, humidity, air pressure, and cloud cover. Climate is the average weather conditions recorded over many years.

4. Earth's atmosphere has a higher concentration of nitrogen and oxygen. Mars and Venus have a much higher concentration of carbon dioxide, no methane, and much lower concentrations of nitrogen and oxygen. Concentration of methane is negligible for all three planets.

6. The relation between temperature and altitude is not a simple, linear one. In the troposphere, the temperature decreases with altitude; in the stratosphere, temperature increases with altitude; in the mesosphere, temperature decreases with altitude; and in the thermosphere, temperature increases with altitude.

7. The ozone layer is a layer in the stratosphere marked by its relatively high levels of ozone.

9. Characteristics of the hydrosphere are as follows:

   - consists of all the water on Earth
   - includes ice, liquid water, and water vapour
   - mainly warmed by incoming sunlight
   - consists of 97% salt water and 3% fresh water
   - total amount of water is constant

10. Answers will vary. Two examples of the effects of climate are as follows:

    - buying a heavier, warmer coat for colder winters
    - using sunscreen and wearing a hat in the hot summer sun

12. Both anecdotal and scientific evidence indicate that climate change is occurring.

16. Insolation is the amount of solar energy received by a region of Earth's surface.

18. The angle of inclination of Earth is 23.5°.

> **Note:** Recall that the angle of inclination is the angle of Earth's axis of rotation. This angle is related to the perpendicular of the plane of Earth's orbit around the Sun.

20. Photosynthesis is the process not (directly) related to Earth's climate.

21. As latitude increases, insolation decreases; or the greater the distance from the equator, the less the insolation.

22. Water reflects more solar radiation than grass. It follows that the albedo of a surface covered by water is more than the albedo of a surface covered by grassland.

24. Water vapour is the main contributor to the natural greenhouse effect.

26. The net radiation budget for all of Earth is almost zero. If the net radiation budget is positive, there is global warming. If the net radiation budget is negative, Earth is cooling.

> **Note:** For a specific region of Earth, it is its net radiation budget that largely determines its climate. Regions with a deficit in their net radiation budget are colder than those with a surplus in their net radiation budget.

29. Thermal energy is transferred by global winds.

33. Wind moves thermal energy between regions having different amounts of insolation.

38. Phase changes occur in different places in the hydrologic cycle. Thermal energy is picked up where water evaporates and released where water condenses.

42. Examples of matter moving into or out of a biome may vary. The migration of birds, the water flowing in rivers, and the movement of airborne materials are just a few examples.

48. The Intergovernmental Panel of Climate Change (IPCC) reports information of climate change to the public.

52. The enhanced greenhouse effect is the change in Earth's net radiation budget caused by the increase in human-generated greenhouse gases.

54. Answers may vary. Evidence of climate change occurring include

    - the shrinking of polar ice caps
    - an increase in the average temperature of oceans
    - a decrease in the average water level of oceans
    - a decrease in the population of polar bears
    - a change in the migration of polar bears

57. The Montreal Protocol is an international agreement to phase out the production and use of CFCs. It was signed in 1987 by Canada and other nations, becoming the first international agreement concerning Earth's atmosphere.

60. Potential consequences of climate change for Canada include

- loss of species in the tundra biome
- more drought, especially in the southern prairies
- more severe weather events
- health threats due to hot weather and pollution
- more immigration due to refugees from drought-ridden regions of the globe
- better agricultural crop yields in northern areas and expansion of farming into new regions

61. An increase in the average global temperature could lead to the shrinking of the Arctic snow and ice cover. By exposing more open water and land, albedo would decrease.

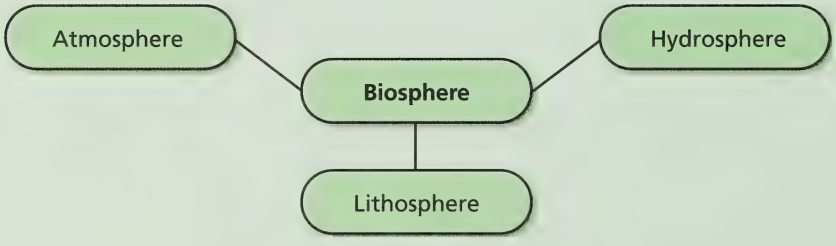
62. *The Government of Canada's Action Plan on Climate Change* proposes actions to reduce greenhouse gas emissions in the Transportation, Agriculture and Forestry, Energy, Buildings, and Industry sectors.

2. **Textbook questions 64, 68, 85, 89, 93, and 96 of "Applications," pp. 437 and 438**

64. The bolded text represents the changes made.

a. The last two weeks of rain have made the **weather** miserable.
b. This kind of **climate** is the reason that good crops grow here every year.

68. Answers may vary. The concept map should convey the idea that the biosphere is composed of the atmosphere, lithosphere, and hydrosphere. A sample concept map is given.



85. $m = 100.0 \text{ kg}$
$= 1.000 \times 10^5 \text{ g}$
$c = 4.19 \text{ J/g•°C}$
$\Delta t = 20.0°\text{C} - 10.0°\text{C}$
$= 10.0°\text{C}$
$Q = ?$

$Q = mc\Delta t$
$= (1.000 \times 10^5 \text{ g})(4.19 \text{ J/g•°C})(10.0°\text{C})$
$= 4.19 \times 10^6 \text{ J}$
$= 4.19 \times 10^3 \text{ kJ}$

The amount of thermal energy that must be used to heat the water is 4.19×10^3 kJ.

89. $m = 200$ g, $M = 18.02$ g/mol, $H_{fus} = 6.01$ kJ/mol, $n = ?$, $Q = ?$

$$n = \frac{m}{M}$$
$$= \frac{200 \text{ g}}{18.02 \text{ g/mol}}$$
$$= 11.098\ 779\ 13 \text{ mol}$$

$$H_{fus} = \frac{Q}{n}$$
$$Q = nH_{fus}$$
$$= (11.098\ 779\ 13 \text{ mol})(6.01 \text{ kJ/mol})$$
$$= 66.7 \text{ kJ}$$

It takes 66.7 kJ of thermal energy to melt the ice.

93. The increases in greenhouse gases were estimated as follows:

- carbon dioxide: 295 ppm to 365 ppm
- nitrous oxide: 0.280 ppm to 0.310 ppm
- methane: 0.900 ppm to 1.750 ppm

96. Effects of climate change on Alberta could be

- generally longer growing season, better crops
- more extreme weather events, such as drought and storms
- more forest pests
- more forest fires
- more respiratory illnesses due to air pollution associated with heat waves

3. **Textbook questions 97, 99, and 104 of "Extensions," p. 438**

97. Changes in climate could be due to changes in energy emitted from the Sun or natural climate cycles. Errors in temperature measures due to placement of data collection near urban areas could give the wrong picture. Also, the lack of understanding of complex interactions of components of the biosphere makes predicting impossible.

99. A biome is considered an open system because energy and matter from the surroundings are inputs into the system and energy and matter leaving the system to the surroundings are outputs.

104. IPCC assessments are reviewed by other scientists to ensure accuracy and lack of bias.

4. **Textbook question 107 of "Skill Practice," pp. 438 and 439**

107. Brochures will vary but should apply information from the climatograph. They should recommend travel in February and March—the driest months with relatively comfortable temperatures. Raincoats should be recommended for any other time of the year.

Congratulations!

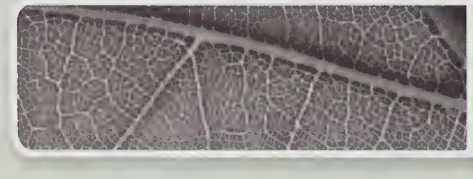
You have now completed

SCIENCE 10

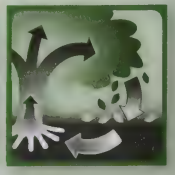
We hope you enjoyed taking this course and that you found it both interesting and rewarding. You should now prepare for the final test by reviewing your assignments and modules.

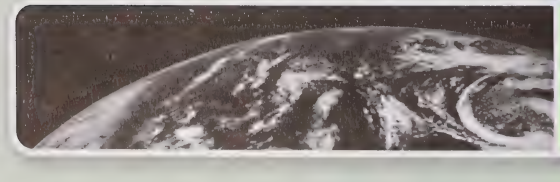
Module 1
Energy and Matter in Chemical Change

Module 2
Energy Flow in Technological Systems



Module 3
Cycling Matter in Living Systems





Module 4
Energy Flow in Global Systems

Course Glossary

absorb: to convert radiant energy into a form of energy associated with a rise in temperature

When a substance absorbs radiant energy, the kinetic energy of its particles increases.

acceleration: a change in velocity during a specific time interval

acid: a compound that, when dissolved in water, forms a solution with a pH less than 7

active transport: the movement of molecules or ions across a semi-permeable membrane against the concentration gradient that requires energy

adaptation: any change in the structure or function of an organism that makes it more suited to its environment; the structure or function itself resulting from adaptation

addiction: a physical dependence on a substance

adhesion: the tendency of unlike molecules to stick together

albedo: the percent of incident solar energy a surface reflects

altitude: the distance above Earth's surface measured from sea level

anecdotal evidence: evidence that relies on reports from people about particular events and their interpretation of these events

angle of incidence: the angle between a ray falling on a surface and the line of the perpendicular to that surface

angle of inclination: the degree by which Earth's poles are tilted from the perpendicular of the plane of its orbit

Earth's angle of inclination is 23.5°.

anion: a negatively charged ion

anthropogenic: resulting from the influence of humans

atmosphere: the layer of gases that surround Earth

atmospheric dust: tiny, solid particles suspended in the atmosphere

atmospheric pressure: the pressure exerted by the mass of air above any point on Earth's surface

atom: the smallest particle of an element that has the properties of that element

atomic molar mass: the average mass of one mole of an element's atoms including all isotopes of the element

auxin: a plant hormone that promotes cell elongation in stem cells as a response to a light source

average speed: the distance travelled in a specified time

Avogadro's number: the number of particles in a mole of any substance

A mole is 6.02×10^{23} particles.

balanced formula equation: a formula equation that has the same number of atoms of each element on both sides of the equation

base: a compound that, when dissolved in water, forms a solution with a pH greater than 7

biochemical reaction: a chemical reaction that occurs in living things

biome: a large geographical region with a particular range of temperature and precipitation levels and the plants and animals adapted to those climate conditions

biosphere: a relatively thin layer of Earth that has conditions suitable for life

boiling point: the temperature at which a substance at normal air pressure changes from a liquid to a gas

buffer: a substance that keeps the pH of a solution nearly constant even when small amounts of acid or base are added

calorimeter: a device used to determine the transfer of thermal energy

capillary action: the movement of a liquid along the surface of a solid

carbon dioxide sequestering: a process of pumping carbon dioxide gas into the ground and storing it in sealed containers

carbon sink: any process that removes carbon dioxide from the atmosphere

e.g., photosynthesis

carbon source: any process that releases carbon dioxide into the atmosphere

e.g., burning of fossil fuels

carrier protein: a protein present in the cell membrane that binds to a specific molecule and transports it across the membrane

catalyst: a chemical that speeds up a reaction

cation: a positively charged ion

cell communication: the ability of cells in an organism to interact with each other and to influence each other's activity

cell membrane: a protective barrier that surrounds the cell and allows the transport of nutrients into the cell and wastes out of the cell

cell theory: the theory stating that all living things are made up of cells, the smallest unit of life, and that all cells come from pre-existing cells

cellular respiration: the breakdown of glucose to release chemical energy that a cell can use

cell wall: a rigid, protective layer around the cell in plants, bacteria, and some protists

channel protein: a protein present in the cell membrane that forms a passageway for specific molecules or ions to pass through

chemical change: the change that occurs when substances react in a chemical reaction to create different substances

chemical energy: potential energy stored in the chemical bonds of compounds

chemical property: a property that describes the reactivity of a substance

chemical reaction: a process that occurs when substances react to form a new substance or substances

chlorophyll: a green pigment that makes photosynthesis possible

chloroplast: an organelle found in plants and some protists that contains chlorophyll and is the site of photosynthesis

climate: the average weather conditions that occur in a region over a long period of time

climate change: a change that occurs in the climate of a region over a long period of time

climatograph: a visual summary of the average temperature and precipitation for each month of the year for a given location

closed system: any system that exchanges energy with its surroundings but does not exchange matter

cogeneration: the use of waste energy from one process to power a second process

cohesion: the tendency of like molecules to stick together

combustion: a chemical reaction that occurs when oxygen reacts rapidly with a substance to form a new substance and release energy

companion cell: a cell connected to and that appears to direct the activities of sieve tube cells

compound: a chemical combination of two or more elements in a specific ratio

concentration gradient: the difference within a given area or region of the highest and lowest concentrations of a substance

conduction: the transfer of thermal energy by direct contact between the particles of a substance, without moving the particles to a new location

confocal technology: a system that uses a light microscope, laser beams, and computers to produce a 3-D image from many images of thin slices of a specimen

contrast: the ability to see differences between structures in an image due to their ability to absorb light

control system: a system within plants that produces definite responses to specific stimuli

controlled variable: a condition that is held constant throughout an experiment

convection: the transfer of thermal energy through the movement of particles from one location to another

Coriolis effect: the deflection of any object from a straight-line path by Earth's rotation

covalent bond: a bond formed when non-metallic atoms share electrons

crystal lattice: an organized array of ions

current: flow from one place to another in one direction

cuticle: a waxy, waterproof coating on leaves and stems that prevents excess evaporation and helps the plant resist attack from micro-organisms

cytoplasm: a gel-like substance inside the cell membrane in which the organelles are suspended

cytoplasmic streaming: the distribution of material within a cell through the circular flow of cytoplasm

decomposition reaction: a chemical reaction in which a compound is broken up into its elements

density: mass per volume of a substance

desalination: the process by which salt is removed from salt water

diffusion: the spontaneous movement of particles from an area of higher concentration to an area of lower concentration

displacement: a vector quantity describing the length and direction in a straight line from the starting position to the final position

double replacement reaction: a chemical reaction in which two compounds react to form two new compounds

ductile: able to be drawn into long thin wires

efficiency: a measure of how effectively a machine converts input energy into useful output energy

$$\text{efficiency} = \frac{\text{useful work output}}{\text{total work input}}$$

elastic potential energy: energy stored in an object when its shape is stretched, twisted, or compressed

electrolyte: a solution that conducts electricity

electromagnetic spectrum: the entire range of wavelengths of electromagnetic radiation extending from radio waves (longest) to cosmic waves (shortest)

electron: a negatively charged particle in an atom that occupies energy levels around the nucleus

electron microscope: an instrument that uses a beam of electrons to produce an image of a specimen

element: a pure substance that cannot be broken down into other substances

emission-reduction credits (ERCs): credits given to a country under the Kyoto Protocol for actions that contribute to the global reduction of greenhouse gas emissions

endocytosis: a process of moving molecules or particles into a cell using a vesicle formed from the cell membrane

endoplasmic reticulum: a network of membrane tubes that branch out from the nuclear envelope and circulate materials throughout the cell

endothermic reaction: a reaction that absorbs energy

energy: the ability to do work

energy input: the initial energy source

energy level: a region near an atom's nucleus that may be empty or may contain electrons

enhanced greenhouse effect: the observed increase in Earth's average temperature

epidermis: the outer layer of cells that covers all plants

equilibrium: a state of balance between opposites actions

equinox: one of two points in Earth's orbit at which the number of daylight hours anywhere on Earth's surface is equal to the number of hours of night

exocytosis: a process of removing molecules or particles from a cell through vesicles that fuse to the cell wall and rupture

exothermic reaction: a reaction that releases energy

extrapolation: a process of estimating the value of a measurement beyond the known values of a set of data

facilitated diffusion: diffusion across a semi-permeable membrane through carrier proteins; does not require energy

field of view: the area seen under a microscope with a given objective lens

first law of thermodynamics: a law stating that the total energy, including thermal energy (heat), in a system and its surroundings remains constant

fluid: any substance that has no definite shape and tends to flow

Gases and liquids are fluids.

fluorescence microscopy: a technique in which fluorescent substances are attached to desired molecules in a specimen that is then subjected to ultraviolet light

formation reaction: a chemical reaction in which two elements combine to form a compound

formula equation: a chemical equation that uses the chemical formulas of the reactants and products to represent a chemical reaction

formula unit: the smallest amount of an ionic compound that has the composition shown by the chemical formula

fossil fuel: a carbon-based fuel formed from the remains of living organisms

e.g., coal, oil, and natural gas

gene mapping: a technique used to locate the position of specific genes within the genetic make-up of an organism

general circulation model (GCM): a climate model that incorporates the laws of physics to model climate on a global scale

Golgi apparatus: a flat stack of membranes that receive, modify, and transport products of the endoplasmic reticulum throughout the cell

gravitational potential energy: energy due to the position of an object above Earth's surface

gravitropism: the growth response of plants to the Earth's gravitational system

Green Fluorescent Protein (GFP) technology: a process that allows cell activities to be studied by attaching green fluorescent protein to particular parts of the cell

greenhouse gas: a gas that absorbs infrared radiation released from Earth's surface

Greenhouse gases contribute to the greenhouse effect.

ground tissue: cells that make up the majority of the plant beneath the epidermis

group: a vertical column in the periodic table; also called family

guard cell: a cell on the lower epidermis of leaves that forms an opening for gas exchange

halocarbon: any of various compounds of carbon and one or more halogens

Halocarbons are human-made chemicals, such as chlorofluorocarbons (CFCs), that absorb large quantitities of thermal energy.

heat engine: a device that converts heat into mechanical energy

heat of condensation: the amount of energy released when 1 mol of a substance changes from the vapour phase to the liquid phase without a change in temperature

heat of fusion, H_{fus}: the amount of energy absorbed when 1 mol of a substance changes from the solid phase to the liquid phase without a change in temperature

heat of solidification: the amount of energy released when 1 mol of a substance changes from the liquid phase to the solid phase without a change in temperature

heat of vaporization, H_{vap}: the amount of energy absorbed when 1 mol of a substance changes from the liquid phase to the vapour phase without a change in temperature

hemodialysis: a process by which blood is circulated outside the body to a dialysis machine, which cleanses the blood and returns it to the body

hormone: a chemical produced by a cell in one location and travels to another location where it produces an affect

hydrocarbon: a compound that contains hydrogen and carbon

hydrocarbon combustion reaction: a chemical reaction in which a hydrocarbon reacts with oxygen to form carbon dioxide and water

hydrochlorofluorocarbon (HCFC): a compound that has similar properties to CFCs but destroys ozone much more slowly

hydrologic cycle: the process by which water molecules move from Earth's surface into the atmosphere and then back again; also called the water cycle

hydrosphere: the water on Earth, whether present as liquid, water vapour, or ice

hypertonic: having a higher concentration of solute than another solution

hypotonic: having a lower concentration of solute than another solution

incident: falling on or striking a surface

indicator: a substance that shows whether a solution is acidic or a basic

e.g., litmus and red cabbage juice

insolation: the amount of solar energy received by a region of Earth's surface

insulin: a small protein produced in the pancreas that influences the movement of glucose into cells

internal combustion engine: a heat engine in which fuel is burned inside the engine itself (rather than in a separate furnace)

inversion: a reversal of normal temperature patterns seen in the troposphere

In an inversion, there is an increase of temperature with height through a layer of air.

ion: an electrically charged atom or group of atoms

ionic bond: a bond formed when electrons are transferred between a metal and a non-metal

ionic compound: a compound formed when electrons are transferred from one atom to another

IPCC: Intergovernmental Panel on Climate Change; an international group of scientists who assess information related to climate change

isotonic: having the same concentration of solute as another solution

isotope: an atom of the same element containing a different number of neutrons

jet stream: a band of fast-moving air in the stratosphere

kinetic energy: energy due to the motion of an object

Kyoto Protocol: an international agreement to reduce the emission of greenhouse gases

latitude: the imaginary lines that run parallel to Earth's equator; the angular distance of a line of latitude north or south of Earth's equator measured from 0° through 90°

lenticel: an area of pores on the bark of some trees that allows gas exchange between the air and the inner part of the trunk

light microscope: an instrument that uses a system of lenses for magnification of a specimen illuminated by a beam of white light

liposome: a fluid-filled sac surrounded by a phospholipid bilayer that is identical to a human cell membrane

Liposomes are used to deliver medication to diseased cells without affecting normal cells.

lithosphere: the solid outer portion of Earth, composed of rocks, minerals, and elements

lysosome: an organelle containing enzymes that digest food, destroy bacteria, and break down damaged organelles in cells

magnification: an increase in the apparent size of an object calculated as the product of the magnifying power of the objective lens and magnifying power of the eyepiece

malleable: able to be beaten or rolled into sheets without crumbling

mass number: an integer equal to the total number of protons and neutrons in the nucleus of the atom

Material Safety Data Sheet (MSDS): an information sheet that identifies the chemical and physical properties of a substance, safe handling, first aid, and cleanup procedures in case of a spill or leak

mechanical energy: energy due to the motion and position of an object

The amount of mechanical energy of an object is equal to the sum of the kinetic energy and gravitational potential energy of the object.

Mechanical energy is also used to refer to the energy of a moving machine part. For example, the turning shaft of an electric motor has mechanical energy due to the twisting force that gives it turning motion.

melting point: the temperature at which a substance at normal air pressure changes from a solid to a liquid

membrane technology: research into the development and use of synthetic membranes in various industrial and medical applications

meristem: an area where cell division occurs, resulting in the growth of the plant

mesophyll: a general term for the two types of tissue found between the upper epidermis and the lower epidermis

mesosphere: the atmospheric layer above the stratosphere, from 50 km to 80 km above Earth's surface

metal: a shiny, malleable, and ductile element

metalloid: an element with properties intermediate between metals and non-metals

mixture: a combination of pure substances

molar mass: the mass of one mole of a substance

mole: a quantity used by chemists to measure amounts of elements and compounds

molecular compound: a compound that forms molecules when non-metallic atoms share electrons

molecular element: an element that forms a molecule made up of only its atoms

molecule: two or more atoms of the same element or of different elements bound together by covalent bonds

Montreal Protocol: an international agreement to phase out the production and use of CFCs

motion: a changing of position of an object relative to a reference point

An object is in motion when an imaginary line joining the object and a reference point changes in length or direction.

multivalent element: an element with more than one stable ion

natural greenhouse effect: the absorption of radiant energy by the atmosphere

net radiation budget: the difference between the amount of incoming radiation and outgoing radiation from Earth's surface and atmosphere

neutral: having a pH of 7

neutralization: a process in which an acid and a base are mixed to form a solution that loses the acidic and basic properties

neutron: a neutral particle in the nucleus of an atom

nicotine: a highly addictive substance present in tobacco

non-metal: an element with varying properties that are completely different from metals

There are 17 non-metals in the periodic table.

non-renewable energy source: an energy source that is limited and cannot be replaced

nuclear energy: the potential energy stored in the nucleus of an atom

nuclear envelope: a double-layered membrane that separates the nuclear contents from the cytoplasm

nucleus: the positively charged centre of an atom made up of protons and neutrons, except hydrogen which has only a proton in its nucleus; the organelle that contains the genetic material of the cell and directs all cell activities

octet rule: a rule stating that atoms bond in such a way that each valence energy level has eight electrons

open system: any system that exchanges both matter and energy with its surroundings

organ: tissues grouped together performing the same functions

osmosis: the diffusion of water across a selectively permeable membrane

ozone: a molecule composed of three atoms of oxygen

ozone layer: a layer in the stratosphere containing high levels of ozone gas

palisade tissue cell: a cell where photosynthesis occurs and found just below the upper epidermis of leaves

passive transport: movement that does not require energy

percent efficiency: efficiency expressed as a percentage

$$\text{percent efficiency} = \frac{\text{useful work output}}{\text{total work input}} \times 100\%$$

period: a horizontal line in the periodic table

peritoneal dialysis: a process that uses the membrane that lines the abdominal cavity to remove waste products from the blood by diffusion into a dialysate fluid

perpetual motion machine: a hypothetical machine in which all the input energy converts completely into mechanical energy; perfect machine

pH: the measure of how acidic or basic a substance is

phase: the state of a substance (solid, liquid, or gas)

phloem tissue: sieve tube cells that transport sugars from the leaves to other parts of the plant

phospholipid bilayer: the double layer of outward-facing phosphates and inward-facing lipids that form a cell membrane

photomicrograph: a photograph taken through a microscope

photosynthesis: the process through which plants convert light energy into chemical energy in the form of glucose

phototropism: the growth response of plants to light conditions

physical property: a property that describes the physical appearance and composition of a substance

plasmolysis: the shrinking of the cytoplasm and the cell membrane away from the cell wall due to the outflow of water from the cell

polar molecule: a molecule that has a positive charge at one end and a negative charge at the other end

polyatomic ion: a charged particle made up of several non-metallic atoms

position: a vector quantity describing the location of a point relative to a reference point

potential energy: energy stored and held in readiness to do work

prairie: a subtype of the grassland biome found in North America

Prairies have a cooler average temperature than savannas (the other subtype of the grassland biome).

precautionary principle: a principle stating that the lack of full scientific certainty will not be used as a reason to postpone measures to prevent environmental damage

precipitate: a solid of low solubility that forms from mixing solutions

pressure-flow theory: an explanation of how plant nutrients are transported from leaves to other parts of the plant, driven by pressure built up by hypertonic solutions in the phloem

product: a substance that is produced by a chemical reaction

proton: a positively charged particle in the nucleus of an atom

pure substance: a substance in which all particles are identical

quantity of thermal energy, Q: the amount of thermal energy absorbed or released when the temperature of a specific mass of a substance changes by a certain number of degrees

$Q = mc\Delta t$

radiant energy: energy that is transmitted as electromagnetic waves

radiation: the emission of energy as radiant energy

reactant: a substance that reacts in a chemical reaction

receptor protein: a protein that binds with certain molecules to bring them into the cell

recognition protein: a protein embedded in the cell membrane that allows cells to recognize each other and foreign materials

reflect: to change the direction of an incident ray as it comes back from a surface

regulated substance: a substance that must be transported and used according to strict guidelines

renewable energy source: an energy source that is continually and infinitely available

resolution: the ability to distinguish between two structures very close together

ribosome: an organelle in the cell that is the site of protein synthesis

root pressure: pressure exerted on water in the roots by osmosis

root system: the part of the plant below the ground (one exception being aerial roots)

savanna: a subtype of the grassland biome found in Africa, Central America, and Australia

Savannas have distinct wet and dry seasons and a warmer average temperature than prairies (the other subtype of the grassland biome).

scalar quantity: a quantity consisting of magnitude only, not direction

Scanning Electron Microscope (SEM): an electron microscope that uses a beam of electrons to scan the surface of a specimen that has been fixed and covered with an electron-dense material, like gold

scientific evidence: evidence collected in a manner that ensures it is unbiased and reflects general situations rather than particular events

Scientific evidence is usually collected by trained scientists and checked by other trained scientists.

second law of thermodynamics: a law stating that heat always flows naturally from a hot object to a cold object and never naturally from a cold object to a hot object

semi-permeable membrane: a membrane that allows only certain particles to pass through; can be naturally or synthetically produced

shoot system: the part of the plant above ground (one exception being tubers)

single replacement reaction: a chemical reaction in which a compound reacts with an element to form a new compound

sink: a place in a plant where products of photosynthesis are stored

skeleton equation: a formula equation that only shows the identities of the substances involved in a chemical reaction

solar energy: energy due to the fusion of hydrogen nuclei on the Sun

solstice: one of two points in Earth's orbit at which the poles are most tilted toward or away from the Sun

solubility: the ability of a substance to dissolve in another substance; a measure of how well a solute dissolves in a particular solvent

source: a place in a plant where products of photosynthesis are manufactured

specific heat capacity, *c*: the amount of energy needed to raise the temperature of 1 g of a substance 1°C

spongy mesophyll tissue: a layer of loosely packed cells that allows for movement of gases within the leaf; found between the palisade cells and the lower epidermis

spontaneous generation: the theory that life could emerge spontaneously from non-living matter

stimulus: something in the environment that causes a reaction by an organism

stomata: openings on the underside of leaves through which the exchange of gases occurs

stratosphere: the atmospheric layer above the troposphere, from 10 km to 50 km above Earth's surface

surface area: the area of the outside shell of an object

surface area to volume ratio: a ratio between the total surface area of an object and its volume

surroundings: everything outside of a system

sustainable: of or relating to any process that will not compromise the survival of living things or future generations while still providing for current energy needs

sustainable development: the use of the world's resources in a way that keeps the resources for future generations

system: a set of interconnected parts; a set of interconnected parts and an associated region containing these parts

teleportation: a hypothetical method of transportation in which matter is dematerialized, usually instantaneously, at one point and recreated at another

thermodynamics: the study of the interrelationships between heat, work, and energy

thermosphere: the highest atmospheric layer, from 80 km to 300 km above Earth's surface

tissue: a group of cells performing the same function together

tonicity: a term that relates the concentration of solute particles in solutions separated by a semi-permeable membrane

Transmission Electron Microscope (TEM): an electron microscope that passes an electron beam through a very thin section of a fixed and stained specimen

transpiration: the process of water leaving a leaf through the stomata

transpiration pull: a pull on water molecules in xylem due to the evaporation of water through stomata or lenticels

troposphere: the atmospheric layer from 0 km to 10 km above Earth's surface

UNFCCC: United Nations Framework Convention on Climate Change; an agreement by the world's nations to act in ways that will stabilize greenhouse gas emissions from anthropogenic sources

uniform motion: motion in a straight line at a constant speed

universal indicator: a mixture of several indicators that changes colour in a solution as the acidity of the solution changes

useful energy: energy needed to perform a task

useful energy output: energy needed to do work

useful work output: work a machine is supposed to do

vacuole: a membrane-enclosed sac in a cell that serves to store nutrients, products of secretion, or fats

valence electron: an electron in the outer energy level of an atom

vascular bundle: a grouping of phloem and xylem along with other associated tissues

vascular tissue: transport tissue formed of cells joined into tubes (phloem and xylem) that carries water and nutrients throughout the plant

vector quantity: a quantity consisting of magnitude and direction

velocity: the speed and direction of an object

vesicle: a membrane-enclosed sac that transports material in a cell; similar to a vacuole

volume: the amount of space inside an object

weather: the state of the atmosphere at a particular place and time with regard to temperature, air pressure, cloud cover, precipitation, and humidity

WHMIS: Workplace Hazardous Materials Information System; a system that provides details on how to store, handle, and dispose of any chemical found in the workplace

wind: the movement of cool air from an area of high atmospheric pressure to an area of low atmospheric pressure

work: the transfer of energy from one object or system to another when a force is applied over a distance

The quantity of work is equal to the product of force and distance ($W = Fd$).

work input: the work done on a machine being used to move a load

work output: the work done by a machine on a load

Work output is equal to the work needed to move a load directly without a machine.

X-ray crystallography: the study of the structure of molecules using X rays, sensors to analyze the scattering of the X rays, and computer technology to analyze the data

xylem tissue: non-living tubes that move water and dissolved minerals up the stem from the roots to the leaves

SCIENCE 10

Energy and Matter in Chemical Change

Energy Flow in Technological Systems

Cycling Matter in Living Systems

Energy Flow in Global Systems